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December 1940

TECHNOLOGY REVIEW

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THE TABULAR VIEW

Winchell Won't. — Best known means least known, as far as language is concerned, through the familiar though paradoxical fact that men generally don't analyze the things with which they are most familiar. Hence through his study of language in its psychological aspects — an undertaking of some ten years — BENJAMIN LEE WHORF, '18, is pioneering along frontiers to be found right in the back yard. How the patterns of English word formation may be given formal expression, and how the resultant formulas enable the linguist to predict much as does the physicist, are questions which he discusses in this issue of The Review (page 61) in explaining the right of linguistics to be regarded as an exact science. Mr. Whorf has investigated spoken Aztec in Mexico, has worked on the deciphering of Mayan hieroglyphs, has lectured on linguistics at Yale. He is a special agent for the Hartford Fire Insurance Company.

Hummingbird. — Former editor of *Aviation*, now coordinator of research for the National Advisory Committee for Aeronautics, whose chairman is Vannevar Bush, '16, S. PAUL JOHNSTON, '21, tells (page 64) of efforts at vertical flight by means of the helicopter. To Da Vinci the idea of the airscrew was provocative; in our own immediate time, realization of its use seems nearing. Mr. Johnston's article constitutes a chapter of his book *Horizons Unlimited: A Graphic History of Aviation*, which Duell, Sloan and Pearce, Inc., have scheduled to appear on December 5.

Palms and Pumps. — Among prehistory's puzzles, how holes were "worried" through hard substances is one of the most interesting. It is not, of course, without fairly thorough answers. In this issue (page 66) a review of these engages LEROY L. THWING, '03, whose tales of other investigations into the records of applied technology are well remembered by Review readers. For some years connected with the New York Museum of Science and Industry, Mr. Thwing is a student of the history of technics.

Bumpers. — Ways of safeguarding drivers of automobiles against sudden death for themselves and for others are an important question to highway engineers, designers, safety engineers, and manufacturers. JOHN W. MEADER, '19, draws on a decade's experience and subsequent interest in the automotive industry in discussing (page 68) the need and two possible methods of securing better control. An economist and statistician, Mr. Meader is a member of the Society of Automotive Engineers.

Long John's Wooden Leg. — How Georges Bank can supply the Dust Bowl's frying pans is a question depending in part on cowskins, nickel, fathometers, hardy men, and the absence of cologne, as RICHARD HALLET reports in an account of voyaging to the fishing grounds aboard a modern otter trawler (page 70). Australia before the World War and the Maine Coast in the dead of winter have earlier been recounted for The Review by Mr. Hallet, who as novelist and fictioneer is well known.

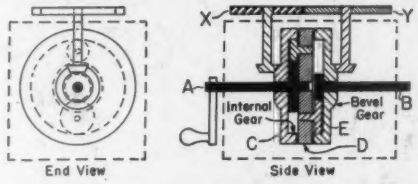
No. 29

Just for Fun!

A CHALLENGE

TO YOUR INGENUITY

THE gear train below can be made to meet last month's puzzle requirements — that there be a true drive connection between shafts *A* and *B* with gears *X*, *Y* as shown, but none with *X* and *Y* interchanged. [*A*, *B* are gear-ended shafts; *C*, *E* each carry internal and bevel gears; *D* carries



two planetary idler gears.] For a given set of gear ratios "inside the box," there is *only one* ratio *R* for *X*:*Y* which positively *connects** *A* and *B*. Find *R*. [What if *X* and *Y* are elliptical?]

* A simpler device *disconnects* for one *R* only.

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MAIL RETURNS

"The Layman's Science"

FROM VANNEVAR BUSH, '16:

"The Layman's Science" in the November Review is a scholarly treatment of a difficult subject. I beg to differ on a couple of points, or perhaps merely to shift emphasis, in the attempt to round out my own thinking on a subject which has always interested me.

The article argues that if the interpretation does not show how the scientific matter treated relates to the personal affairs of the reader, the interpretation will not take. If personal affairs are understood as including the building of an individual cultural pattern and philosophy, I might agree. If by everyday affairs we mean merely food, clothing, shelter, and so on, then there should be no appeal in astronomy; but there certainly is. True, some phases of astronomy advance physics, which in turn does very practical things for us; but the other, the philosophical phase of astronomy, which by no stretch affects our physical ways of living, has had enormous popular appeal.

This is important. Whole areas of scientific effort can be interpreted as of only general cultural interest, for their whole aim is to broaden and clarify matters which are impractical. Archaeology, paleontology, astronomy, much of geology, part of many sciences, have proved to be of intense interest to many and could undoubtedly be of interest to many more if interpreted with complete skill. Such interpretation cannot be done by a writer who thinks the public is interested only in matters that affect it personally.

"The usual reader lacks not only the special training necessary to a comprehension of the immediate event but also an understanding of the sequence of previous developments which made that event possible. . . ." This thought also runs through the essay. I think it has been much overemphasized and that American science writers in general write down unduly. If the object is to write so that all can understand, the case is hopeless. Science can be effectively interpreted only for those who have more than the usual intelligence and innate curiosity. These will work hard if given a chance and if they find they acquire something by so doing. (Witness Eddington's *The Nature of the Physical World.*) The trouble is that, in the hands of the usual science writer, they seldom get the chance.

One more point: The urge to create, to do original thinking, or to make new things, is exceedingly strong in many individuals and much more widespread than is ordinarily appreciated. With this urge as an incentive, very large numbers of people will read carefully and often expositions of matters which to the scientist are commonplace — an example was the long series of articles on elementary physics when homemade radios were the vogue. This fact also has not been sufficiently realized by those who interpret. Of course this is not the only reason that people read articles on science; some, for example, read science as a "must" in the same way that they labor through the book of the month. I venture that if an analysis of reader demand could be made, the result would surprise us all. If writers think they are catering to an audience which wishes only to marvel at the spectacular or to have its everyday affairs enlarged upon, I believe they are reaching only a small fraction of their potential readers.

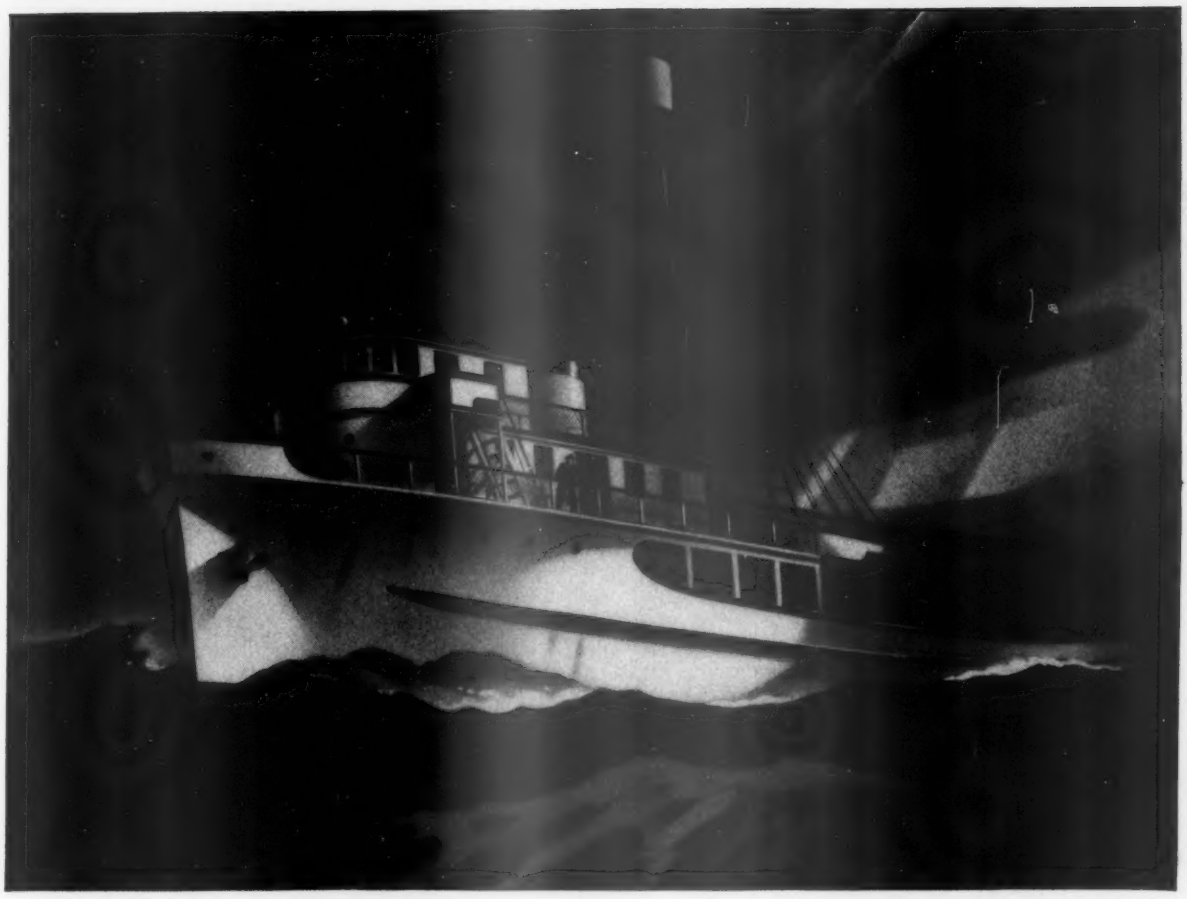
Washington, D. C.

Copia Verborum

FROM FRANK G. SMITH, '11:

Please bear in mind that I am not a literary critic, but I am so taken aback with reading "The Layman's Science" in the November Review that I must indulge in some good-humored raillery. I am always interested in reading The Review because it covers the news of the Institute very well. Altogether, it is a fine publication. "The Layman's Science," however, seems to me to fall far below the usual standard. The discussion is based on the difficulty of "translating" with reasonable accuracy the scientist's into the layman's language. The authors have used a style which is neither easy to read nor understand. Paragraphs are padded with long words which look important but almost need translating. They have fallen into the same pit with that scientist who cannot write his story in simple words. Their own story is difficult to read.

Did the editors make use of the reference to *Science* as quoted: "Science popularizers should write simply . . . . and clearly . . ."? Consider the first sentence of the third paragraph: "The question of adequate popularization becomes more difficult and more important as the material to be popularized increases in complexity or strangeness." Would it not be easier to read and (*Concluded on page 89*)



4140 GOES TO SEA

It is well for all concerned that builders of marine Diesels make performance capacity the primary basis for the selection of materials. Breakdowns at sea or anywhere else are no fun for anyone, including the engine builder.

But the demand for reliability can be met and production costs still kept where they should be. One prominent builder, for example, is doing both by specifying Chromium-Molybdenum (SAE 4140) steel for a number of parts including bolts, wrist-pins, cylinder head studs, gears, tappets and crankshafts.

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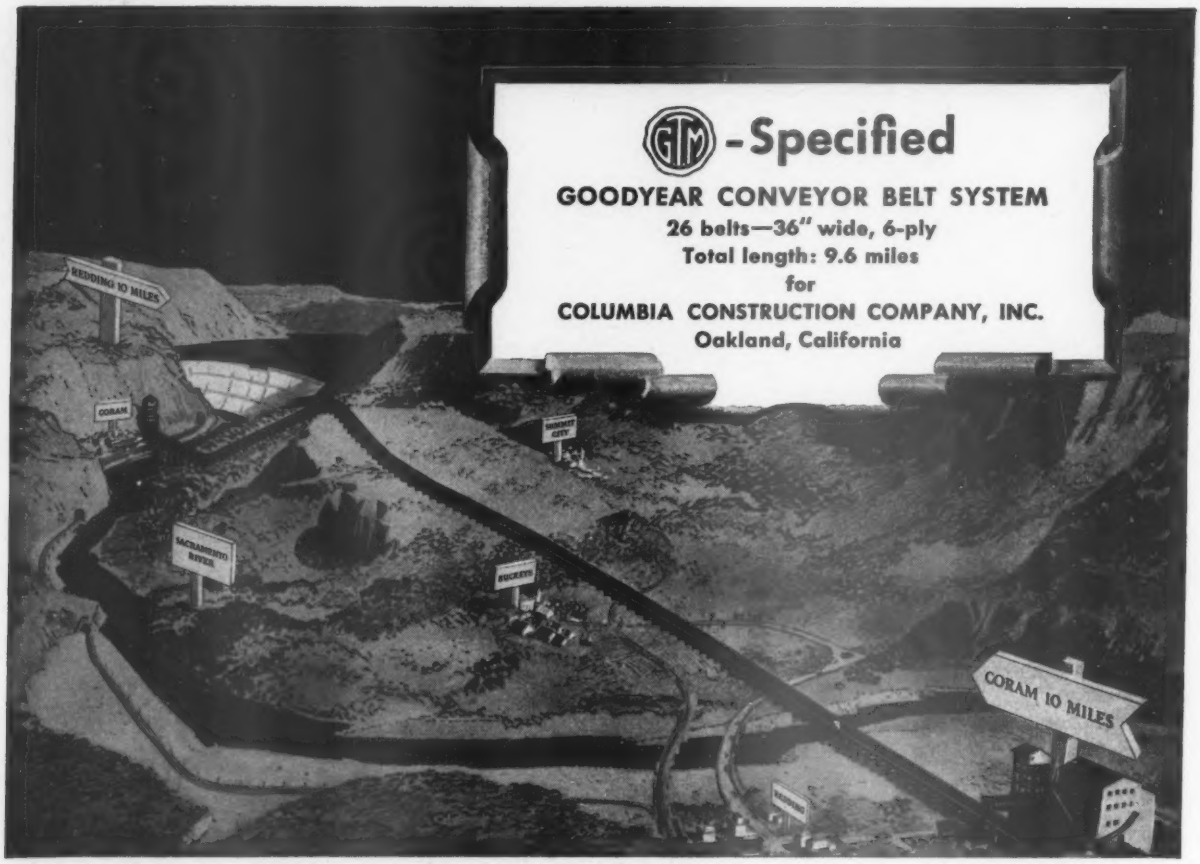

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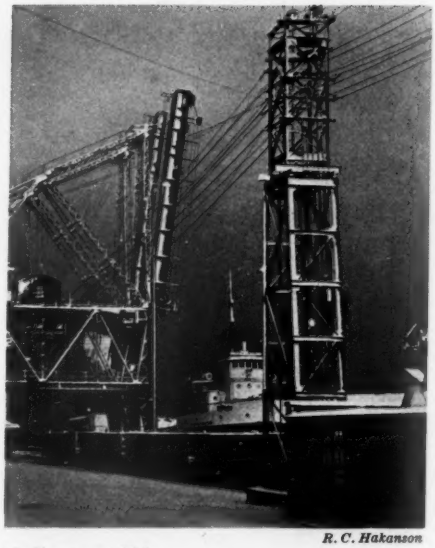

R. C. Hakanson

At Conneaut, Ohio, on Lake Erie, of a winter's day

VOLUME 43 NUMBER 2

THE TECHNOLOGY REVIEW

TITLE REGISTERED U. S. PATENT OFFICE

EDITED

AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONTENTS for DECEMBER, 1940

THE COVER — STAIRWAY IN PARIS
From a photograph by F. S. Lincoln, '22

AT HONOLULU . . . . . FRONTISPIECE 54

LINGUISTICS AS AN EXACT SCIENCE . . . . . BY BENJAMIN LEE WHORF 61
New Ways of Thinking, Hence of Talking, about Facts Alter World of Science

FLYING UP . . . . . BY S. PAUL JOHNSTON 64
Practical Helicopter Would Realize an Idea Older than Aviation

BORING HISTORY . . . . . BY LEROY L. THWING 66
Ancient Workers Drove Holes with Flint Drills and Core Drills

MOTOR NECROLOGY . . . . . BY JOHN W. MEADER 68
If Drivers Cannot Control Cars, Ways of Controlling Drivers Must Be Considered

NET RETURNS FROM THE BANKS . . . . . BY RICHARD HALLET 70
Otter Trawls in the Modern Manner Gather Tons of Fish

☆ ☆ ☆

THE TABULAR VIEW 49
Contributors and Contributions

MAIL RETURNS 50
Letters and Pictures from Review Readers

THE TREND OF AFFAIRS 55
News of Science and Engineering

THE INSTITUTE GAZETTE 73
Relating to the Massachusetts Institute of Technology

Published monthly from November to July inclusive on the twenty-seventh of the month preceding the date of issue, at 50 cents a copy. Annual subscription, $3.50; Canadian and foreign subscription, $4.00. Published for the Alumni Association of the M.I.T.: Henry E. Worcester, President; A. Warren Norton, John E. Burchard, Vice-Presidents; Charles E. Locke, Secretary; Ralph T. Jope, Treasurer. Published at the Rumford Press, 10 Ferry Street, Concord, N. H. Editorial Office, Room 3-219, Massachusetts Institute of Technology, Cambridge, Mass. Entered as second-class mail matter at the post office at Concord, N. H. Copyright, 1940, by the Alumni Association of the Massachusetts Institute of Technology. Three weeks must be allowed to effect changes of address, for which both old and new addresses should be given.

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AT HONOLULU

From this cliff, according to ancient Hawaiian legend, Kamehameha the Great, Hawaii's first monarch, had his enemies hurtled into the valley a thousand feet below.

THE
TECHNOLOGY
REVIEW

Vol. 43, No. 2 December, 1940

The Trend of Affairs

Why Gertie Galloped

COLLAPSE of the Tacoma Narrows Bridge over Puget Sound at Tacoma, Wash., recently was starting point for various official inquiries from which engineering studies may be expected to result and to shed light eventually on the exact causes of failure. Nicknamed "Galloping Gertie" by residents of the region because of its tendency to sway exceedingly with the wind, the bridge had by its antics occasioned considerable speculation before it crashed 190 feet into the waters of the sound on November 7 in a 42-mile wind. Completed last July, it had the third longest center span in the world—2,800 feet—with two 1,100-foot side spans.

Careful study by vibration experts, correlated with observed behavior, motion pictures, and model tests, may be expected to clarify the question of why the bridge failed. The detailed considerations may well be underlaid by certain general conclusions. The vibration which led to the crash of the bridge seems generally agreed to have been caused by wind — an occurrence almost unprecedented for such bridges even though steady winds have long been known to produce destructive vibrations in other structures. Sleet-covered transmission lines, for example, have been observed to "gallop" through twenty-foot vertical distances under the influence of steady wind. Transmission-line strands have broken in fatigue from vibration caused by wind eddies on the leeward side of the wires. Airplane wings have broken off because of "flutter" occurring in power dives. All three of these causes of failure are well known in the special cases mentioned but seemed hardly to be expected in such massive structures as bridges. From tests of models and from observation and study of the bridge vibration itself, however, it appears evident that the vibration was actually a manifestation of one or more of these phenomena.

The Narrows Bridge differed from comparable suspension bridges principally in extremity of design, having a span-to-width ratio of seventy-two as compared to forty-eight for the Golden Gate Bridge. Instead of the more common stiffening trusses, large plate girders were used on the Narrows Bridge. Although in post-mortem these differences appear significant — hindsight always being easier than foresight — their possible importance in the Narrows Bridge could hardly have been anticipated in the light of previous experience.

Galloping and flutter have often been demonstrated on simple models. Having observed the Narrows Bridge at first hand during its months of annoying "bouncing," Blake Mills, '35, instructor in mechanical engineering at the Institute, has by means of a model illustrated a phenomenon something akin to transmission-line galloping as a possible cause of the vibration. In a small wooden model of a stiffening girder, supported on springs and placed in the air stream of a fan, a rather violent and continuous gallop is readily built up. This model is similar to one devised by Professor J. P. Den Hartog of Harvard to illustrate galloping of other types of member. A flat wooden slab, substituted for the girder model in the air stream, readily flutters violently with a combined bouncing and rolling motion somewhat similar to the photographed motion of the deck of the Narrows Bridge just before failure. No model has been built by Mr. Mills to show vibration caused by wind eddies, but a common example of this phenomenon is offered by telephone wires which "sing" in the wind.

Recognition in the Tacoma Narrows Bridge of any or all of these three types of wind-excited vibration by no means leads to a direct solution of the problem of failure. It may serve a purpose, however, in pointing out that on a structure designed for steady loads, dynamic load may in some cases be produced by steady wind. Violent vibrations hence can result from perfectly steady winds,

The glory-hole spillway at Owyhee Dam in Oregon is a vertical shaft of the record height of 309 feet, which diverts waste water to a tunnel passing far under the base of the dam and discharging into the river. At the crest the glory hole is 60 feet in diameter. The single ring gate controlling the full circle of the crest is the first of its kind. Above: *crest during construction.* Right: *ring gate in raised position during test.*

and there are evidently situations where structural designs must reckon with this fact.

Science in War

IN every independent nation of the world which indulges in higher education, scientists are today working against time — a few seeking impregnable means of defense, many more looking for invincible methods of attack. These men would be less than human if they did not in some measure enjoy their task, yet according to the writing of scientific pundits for more years than one can count, it is contrary to all that science stands for.

American men of science have come so recently to the mill that as yet they have done little more than help purposefully to turn the stones. In Britain, on the other hand, this affair has been going on for considerable time; some scientists have stopped to take stock, and have written about their stocktaking in a book, *Science in War*,* now available in America.

The discussion is entertaining and instructive. For the most part it deals with what science might have been able to do and might still be able to do for Britain in her current war. After an introduction, to which reference may more profitably be made later, the text begins with familiar illustrations from the past, such as Leblanc's invention, in 1787, of a new method for making soda. From today's events, authors choose the tale of the magnetic mine and its defeat through the process of degaussing ships. An extensive section on the airplane contains the suggestion that science might have quite as many useful things to say about air-combat tactics as it does about flight characteristics.

Some of the most vigorous pages are from the notes of an officer in the recent Spanish campaign and describe efforts to defeat the tank. These efforts were a sort of large-scale field study, employing the method of try and fail, though the ending is reported to have been happy. From this experience the authors conclude that research might have saved a great deal of time, in fact might have solved the problem in three months. They point out that empirical tests in battle may not give results until a war is lost. This section ends on a pessimistic note: "Indeed, those who despair of getting things done, might well wonder if the empirical research carried out by the Spaniards will not prove to have been far more rapid and effective than anything that will be possible with the war machine of our country — dominated as it is by an apparently unscientific war-office hierarchy."

For medical science the book has a better word to say, describing with enthusiasm several relatively new ideas — the use of Epicutan from the juice of half-incubated chicks to stimulate cell growth; the employment of vitamins in healing; the possibilities in chemotherapy in caring for wound infections, such as those of streptococcus, which are hard to treat by serum therapy; the plaster-sealed treatments of the Spanish campaign; and, for transfusions, typed bloods preserved in bottles. The principal recommendation in this section is for more research on shock.

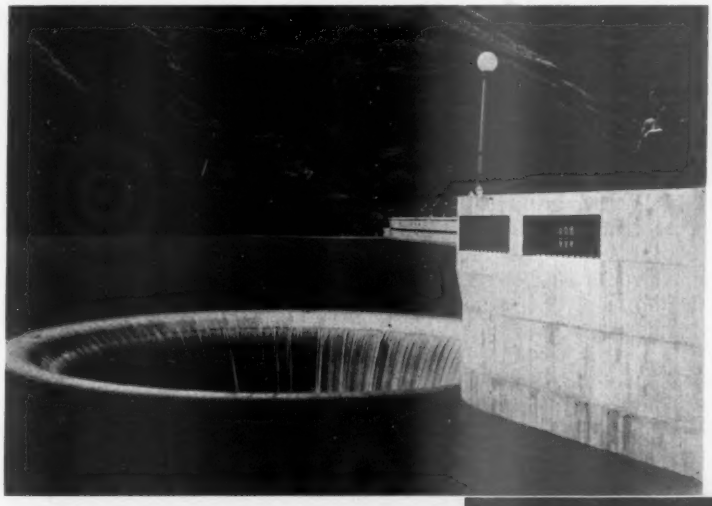
It is a bit of a surprise, but only at first glance, to find so much of the book devoted to food. Much is said about Britain's failure to cultivate her own lands scientifically; a strong plea is entered for a serious study of insect pests, which even in ordinary times destroy one-tenth to one-fifth of all the vegetable crop from British farms; a delightful section deals with the modes of British stock

* Harmondsworth, Eng., and New York: Penguin Books, 1940. 140 pages, 25 cents. The authors are anonymous, but the ideas indicate that their names, if known, would command respect.

selection, which is based primarily on how well the single animal will show on points. The established principles of genetics are, it appears, largely ignored, or at any rate those desirable for breeding race horses are imposed on the breeding of pigs, cattle, and sheep. Speaking of the pig, the authors remark that "the colour of the ears has often been more important than the capacity to suckle the young." The discussion of food supply ends with a proposal that a blueprint be drawn up for national communal feeding, although the authors recognize that "tampering with feeding habits is one of the surest ways of arousing public resentment. . . ."

From all this, it will be realized that here is a book jam-packed with ideas which will warrant reading by any thoughtful man. So far as the book is a program for what might have been, or even a program for what might be, it is reasonably satisfactory. But the authors have a further and deeper purpose. They propose to show why such a program was not in force and to explain how it may in the future be in force.

The introduction urges, again, that science "does not stand outside the ordinary ways of acting and thinking" but is merely the most orderly of these ways, and that therefore science is more needed now than in the past.



Above: *radially converging flow of a thin film of water being discharged over ring-gate crest.* Right: *Starting on its 300-foot plunge, a flow 2½ feet deep is glassy smooth.*

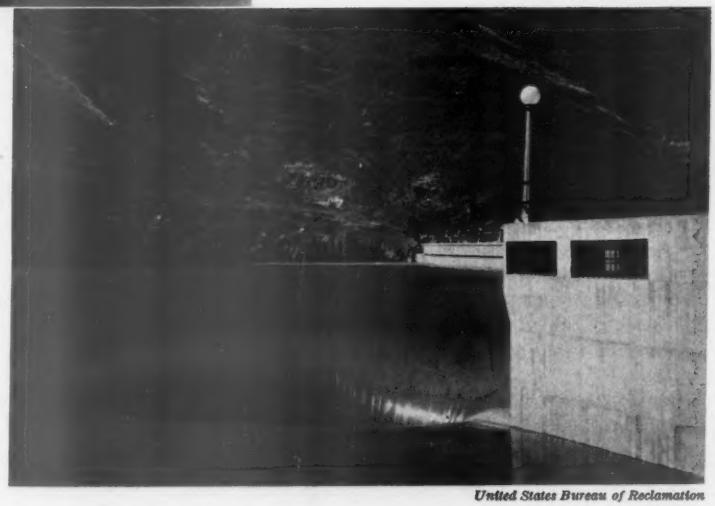
Much is made of the fact that it is not enough for science to solve problems now seen to exist; not enough to follow established and traditional methods of thought and action. Accordingly, the plea is made that science be permitted to survey the whole field of war, including the domain of military tactics, instead of being limited to the pedestrian roles of unstopping bottlenecks in industry or of devising improvements to accepted military devices.

As reasons why science has not been permitted to do so, the authors offer that commercial organizations are too secretive; administrative officers are dominated by technical advisers who are cut off from the more active stream of scientific thought; civil servants lack initiative; business and government tend to regard scientists merely as consultants; centrally located advisory scientists tend to become yes men; scientists are excluded from discussions on policy and especially from making decisions. It is stated that "a general and organized scientific approach to the problems of national existence is foreign to the tradition of both the economic and political management of this country."

The writers of the book have no intention of letting matters rest with propounding the dilemma; they set out to resolve it. Their resolution, too, follows familiar lines. It starts by stating that until recently not a single working scientist was a member of the House of Commons. Apparently this lack was a bad thing. But in the next breath the writers remark: "And on those rare occasions when a scientist has joined the Cabinet or the higher ranks of administration, he has generally left scientific modes of action outside the door of the Cabinet room, and has vied with the rest in Platonic methods of ascertaining truth." Confusion seems to exist here between using the scientific method in society and having scientists as the people who run society.

The solution for all these difficulties lies, according to the writers, in better publicity. If science, and especially scientists, only be known to the public, scientists will perforce be placed at the head of things, and by an equally violent *non sequitur* they will of course shortly put things to rights. One might have a science service; one might have an association of scientific writers, as in America; one might increase the number of good scientific articles in the press; one might distribute scientific films; above all, one might use the B.B.C.

That the excellent preparatory material leaves the reader on such an anticlimax is a great pity. For the conclusions really suggest the addition of two quotations. From Phaedrus, Plutarch, and Horace we might



United States Bureau of Reclamation

draw the reference to the labor of the mountain. And when the mouse inevitably comes out, we might add with Omar that he came out the same door through which in he went. This is very much too bad, for despite the disappointment of their conclusions, these scientists have clearly defined the issues that must be met and have supplied able summary of both deeds and aims.

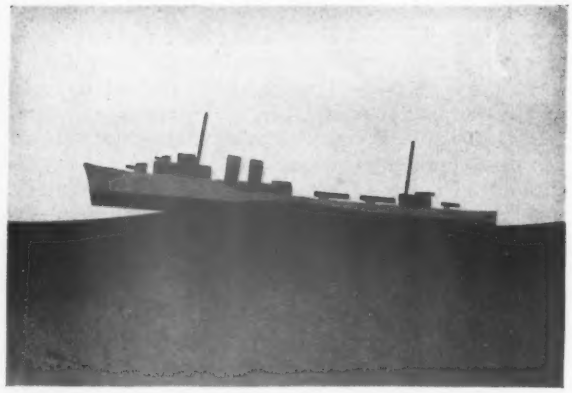
Industrial Vitamins

SHARP increases in the prices of diamonds since the start of the war — significantly, several times as much for industrial diamonds as for the bigger and more nearly perfect jewelers' stones — draw attention to a class of materials which are irreplaceable in a mass-production economy as we know it, but which are used in such comparatively small amounts and to such large effect that they may be likened to vitamins in biological processes. These are the extremely hard materials, such as aluminum oxide, the cemented carbides, and high-speed steels, which grind, cut, draw, and hammer the products of industry into shape. Without them the jobs might somehow be done, but not with the speed and efficiency that give industry its vitality. Mass production depends on interchangeability, which depends on split-hair accuracy, which, in turn, can be obtained at what we now consider reasonable costs only by the use of these keen-edged, heat- and wear-resisting tools.

In 1939, a top year, the world produced about two and a half tons of diamonds, of which over one-half went into industry. In 1936 the entire world output of cemented carbides was in the order of fifty tons. Like diamonds, however, the material is spread thin; it is estimated that every pound of cemented metal carbides is fashioned into an average of ninety parts. Synthetic abrasives, mainly silicon carbide and aluminum oxide, make a more impressive showing, the production in the United States and Canada running to about 100,000 tons a year; yet this figure still represents a minute fraction of the metals, minerals, and plastics which are processed by synthetic abrasives.

The effect of the superhard materials on production is indicated by the reaction of *The Engineer* (London) for September 7, 1900, which noted with astonishment that the newly invented high-speed steel of Taylor and White worked as well when red hot as when cold. "The average quantity of metal removed per hour" [in the shops of the Bethlehem Steel Company], it adds, "has augmented from 31·18 lb. to 137·3 lb., . . . a gain of . . . 340 per cent." From a greater perspective, C. C. Furnas says in a report of the National Resources Committee: "This introduction of one simple improvement [high-speed tool steel] so changed the industrial picture in this country that the efficiency of all industries underwent an estimated increase of 15 per cent. . . . about 8 billion dollars per year."

The high-speed steels, usually containing tungsten, chromium, and vanadium, hold most of their hardness up to temperatures as high as 950 degrees Fahrenheit, whereas alloys composed solely of cobalt, chromium, and tungsten maintain excellent properties up to about 1100 degrees Fahrenheit. The spectacular performances of both when made into dies, cutting tools, and wear-resisting parts arise in large measure from their content of extremely hard and stable metal carbides. To obtain fullest advantage from these remarkable compounds, tools and machine parts are now made which consist only of tungsten, tantalum, and titanium carbide particles cemented together with as little as 3 per cent of cobalt. Specimens of cemented carbides have registered the record moduli of elasticity and compressive strength.



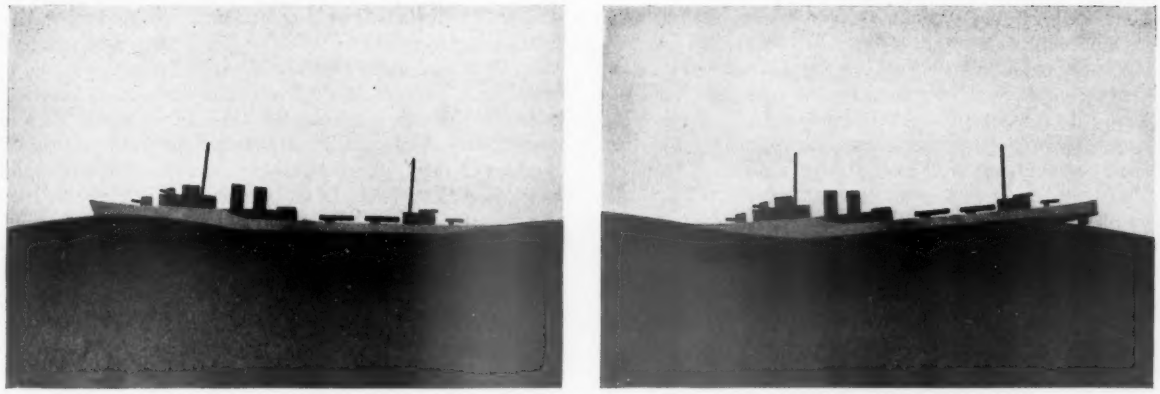
Given a certain vessel, given a certain wave . . .

Because the carbides are harder than any metals, therefore incapable of being fabricated by any machining operations except grinding, and are about as hard as the commonly used abrasives, they must be finish-ground on diamond-impregnated wheels. The diamond is not new to industry, having long been used for truing grinding wheels of the next hardest substances — boron carbide, silicon carbide, and aluminum oxide — and for cutting nonferrous metals and plastics, to which it gives surfaces unsurpassed for smoothness and accuracy. But the importance of the diamond has naturally increased with the rise of the cemented metal carbides. Incidentally, the best industrial diamonds are not the clear, glittering variety but the black stones of Brazil, whose many tiny crystals arranged at random give maximum insurance against cleavage. Likewise, the small crystals which are all that can be produced synthetically at the moment are well suited for industrial use.

These hard materials are hard because of the strength with which their individual atoms are held in their crystal lattices. Almost without exception, therefore, materials of extreme hardness also have very great chemical stability, high melting points, and excellent resistance to corrosion. Where costs allow, and they do with the synthetic abrasives, such materials perform outstandingly as refractories and in chemical apparatus. Thus, by the grace of Edward G. Acheson and his successors, we have the spectacle of aluminum oxide, the stuff of which rubies and sapphires are made, being used to line glass furnaces.

Sailing Synthetic Seas

SEAFARERS who have stood well forward on the deck of a vessel bucking a head sea can easily recall her strange motion — a mysterious combination of dogged forward drive, sudden swift downward drop,



. . . this is the heaving and pitching that will result, as calculated by use of the cinema integraph.

apparent indecisive halt, slow shuddering upward rise, then forward drive again, and the whole cycle repeated. The motion of a ship in such a sea is a complicated thing, and naturally enough the stresses set up in the complex fabric of the vessel are the intricate result of multifarious and involved factors. Knowledge of the pitching and heaving motion of a vessel in such circumstances may contribute significantly to the design of ships, permitting, for example, a better estimate of hull stresses, of necessary freeboard, and of other considerations contributing to seaworthiness and safety. The computation of both the motion and the consequent stresses is obviously a very arduous task.

Devotees of Rudyard Kipling who know his story of "The Ship That Found Herself" are familiar with what may be called the poetic determination of what happens to a ship in a seaway. The beams, plates, and rivets of Kipling's vessel — endowed by him with life and personality — learn during their first voyage the secret of coöperation, so that the vessel herself takes on individuality. Mathematical prediction of what may happen to a ship in such circumstances has in the past been forced to rely upon too ideal assumptions and has been handicapped by computational limitations. A speedier way of getting at figures both for the heaving and pitching motions of a ship in a seaway and for the shearing and bending stresses resulting from them in the hull could be expected so to reduce the time cost that such calculations may become practicable in routine design.

Such a method is suggested by results that have been secured in application of the cinema integraph to this problem in the laboratories of the Department of Electrical Engineering at Technology. Professor Harold L. Hazen, '24, Head of that Department, who with Gordon S. Brown, '31, Assistant Professor of Electrical Engineering, built the cinema integraph under the supervision of Vannevar Bush, '16, has recently, with Paul T. Nims, '40, reported to the Society of Naval Architects and Marine Engineers a trial calculation, using the machine to reckon the pitching and heaving motion of a ship in a head sea, after which the resultant stresses were readily evaluated.

Readers of The Review will recall, from the account of the cinema integraph in our issue for November, 1939 (page 10), that the machine secures its results essentially by the measurement of quantities of light which represent variables in the problem under consideration. Sections of motion picture film are masked off in such a way that the transparent portion remaining represents one variable. Similar arrangements are made for the second variable. Light passed through these transparent portions is collected in a hollow sphere and actuates a photocell which in turn actuates recording mechanisms.

In the ship problem, one film was made to represent a wave of standard trochoidal form, 401.5 feet long and 20 feet high from trough to crest. The frames of the second film carried sections of the hull of a destroyer of 2,100 tons' displacement, 365 feet in length. With a given hull frame and a given wave frame in line, the amount of light transmitted causes an automatic registration of the buoyant force of the wave at a given point on the hull. Working rapidly from point to point in this fashion, the machine computes the buoyant force on the entire ship for a given moment of time. A series of these calculations for succeeding moments permit determination of the ship's motion. Stresses then are determined, including the effect of the motion already figured.

This investigation was experimental in that it was aimed at finding out the technique of applying the cinema integraph in a new kind of work. Initial assumptions concerning the ship were therefore somewhat broad. This study involved but one type of vessel, one set of conditions of loading, and a series of but one type of wave — circumstances absurdly simple as compared with those of a real ship in a real sea. It served, however, to demonstrate that the cinema integraph offers promise for more rapid performance of standard or routine calculations and, more challenging, for extension of analytical as against empirical methods in design.

The calculated motions of the hypothetical destroyer used in this investigation provided data for an animated-cartoon moving picture showing the ship in a seaway. From this the illustrations above are taken.

On Grandpa's Knob

AN experimental development of no little interest is scheduled soon to be under way atop Grandpa's Knob, a peak on a Green Mountain ridge near Hubbardton, Vt. There, incorporating studies that have

extended over the past five years, a Gargantuan wind turbine is to be erected, designed to find out how effectively New England winds can be put to work in the generation of electricity on a larger scale than has heretofore been attempted. Meteorological observation has shown the region to possess a wind-energy regime higher than the average for the country as a whole. The Great Plains and various marine islands have been found also to offer suitable locations for such installations.

A tower over 100 feet high will carry the wind turbine, whose function is to drive a 1,000-kilowatt generator. The turbine's stainless-steel blades, which resemble airplane wings, have a wing spread about as great as that of a large modern bombing plane. Centrifugal forces on the turbine hub are of course enormous and have offered unusual problems in structural design. Accurate regulation of the speed of the generating unit has presented another interesting difficulty; without such regulation, wind gusts would raise the output from 1,000 to 3,000 kilowatts in less than three seconds, seriously overloading the generator. The uncertainties necessarily present in testing a new development of such magnitude include questions like that of the possibility that ice in large fragments will be thrown from the blades during their rotation. These considerations have led to a decision to run the test unit by remote control from a stout dugout in the near-by rock, a station which, in the ruggedness of its construction, will resemble a bombproof shelter.

Daily wind-gauge readings during an extended period as well as many other tests at points throughout the Green Mountain region have provided data used during design of the test turbine. A second tower nearly 200 feet high will be built at the experimental site to carry meters measuring air flow. These meters will make possible an extended investigation of gust velocities and gradients on mountaintops. The turbine is not intended to supplant existing sources of supply. The wind station can increase the value of existing generating sources by backing them up with predictable wind power, and they in turn can complement the wind station when it is becalmed. The worth of wind power, it is felt, might be further extended through use of it to supply energy for electrochemical and other operations which do not require continuous supply. Hence wide industrial applications are seen for wind-generated electricity once its low-cost availability has been demonstrated.

From an industrial engineering standpoint, the project is interesting not only because of the relatively large investment necessitated even during the pioneering stages. For one thing, it is unusual for a test installation of such size to be made at full scale outright, with no intermediate stage of small-scale model testing for the unit as a whole. In the development of the turbine, the designers have preferred to build additional factors of safety into the final product with the money and time that would have been demanded for the construction of a suitable small-scale test device. The unit is so involved that a small model, comparatively speaking, would have been very costly as an engineering undertaking, and hence the differential in cost between full scale and small scale was not so great. Uncertainties in the extrapolation of data from small-scale tests were another factor in the decision to go direct from blueprints to full-size construction. Extensive wind-tunnel testing was of course done during preliminary aerodynamic studies.

The project is somewhat out of the usual likewise in the wide range of scientific and engineering information upon which it has drawn, including the work of investigators widely separated throughout the country, among them many Alumni and staff members of the Institute. The turbine itself is from the designs of Palmer Cosslett Putnam, '23, project engineer for the undertaking. Chief engineer of the project and general structural consultant is John B. Wilbur, '26, Associate Professor of Civil Engineering at Technology. Meteorological studies are under the charge of Sverre Petterssen, Professor of Meteorology at Technology.

Joseph S. Newell, '19, Professor of Aeronautical Structural Engineering at the Institute, was consultant on the design of the blades. Theodore von Kármán, director of the Daniel Guggenheim aeronautical laboratory at the California Institute of Technology, is in charge of aerodynamics in connection with the undertaking. John F. Haines, '34, has served as consultant on aerodynamic and mechanical problems. On the meteorological front C.-G. A. Rossby, assistant director in charge of research of the United States Weather Bureau; Charles F. Brooks, director of Harvard University's Blue Hill Observatory; Hurd C. Willett, Associate Professor of Meteorology at the Institute; and Karl O. Lange of the Blue Hill staff have been consultants. Other Institute people active in the development are Charles H. Norris, Jr., '31, Frederick G. Lehman, '39, and Myle J. Holley, Jr., '39, of the Department of Civil Engineering; Walter

(*Concluded on page 91*)

Robert H. Smyth, '28

Textures and shadows in a pile of future paper

Linguistics as an Exact Science

New Ways of Thinking, Hence of Talking, about Facts Vastly Alter the World of Science, Emphasizing the Need for Investigation of Language

By Benjamin Lee Whorf

THE revolutionary changes that have occurred since 1890 in the world of science — especially in physics but also in chemistry, biology, and the sciences of man — have been due not so much to new facts as to new ways of thinking about facts. The new facts themselves of course have been many and weighty; but more important still, the realms of research where they appear — relativity, quantum theory, electronics, catalysis, colloid chemistry, theory of the gene, Gestalt psychology, psychoanalysis, unbiased cultural anthropology, and so on — have been marked to an unprecedented degree by radically new concepts, by a failure to fit the world view that passed unchallenged in the great classical period of science, and by a groping for explanations, reconciliations, and restatements.

I say new ways of *thinking* about facts, but a more nearly accurate statement would say new ways of *talking* about facts. It is this *use of language upon data* that is central to scientific progress. Of course, we have to free ourselves from that vague innuendo of inferiority which clings about the word "talk," as in the phrase "just talk"; that false opposition which the English-speaking world likes to fancy between talk and action. There is no need to apologize for speech, the most human of all actions. The beasts may think, but they do not talk. "Talk" *ought to be* a more noble and dignified word than "think." Also we must face the fact that science begins and ends in talk; this is the reverse of anything ignoble. Such words as "analyze," "compare," "deduce," "reason," "infer," "postulate," "theorize," "test," and "demonstrate," mean that whenever a scientist does something, he talks about this thing that he does. As Leonard Bloomfield has shown, scientific research begins with a set of sentences which point the way to certain observations and experiments, the results of which do not become fully scientific until they have been turned back into language, yielding again a set of sentences which then become the basis of further exploration into the unknown. This scientific use of language is subject to the principles or the laws of the science that studies all speech — linguistics.

As I was concerned to point out in a previous article, "Science and Linguistics," in The Review for April, we all hold an illusion about talking, an illusion that talking is quite untrammeled and spontaneous and merely "expresses" whatever we wish to have it express. This illusory appearance results from the fact that the obligatory phenomena within the apparently free flow of talk are so completely autocratic that speaker and listener are bound unconsciously as though in the grip of a law of nature. The phenomena of language are background phenomena, of which the talkers are unaware or, at the most, very dimly aware — as they are of the motes of dust in the air of a room, though the linguistic phenomena govern the talkers more as gravitation than as dust would. These automatic, involuntary patterns of language are not the same for all men but are specific for each language and constitute the formalized side of the language, or its "grammar" — a term that includes much more than the grammar we learned in the textbooks of our school days.

From this fact proceeds what I have called the "linguistic relativity principle," which means, in informal terms, that users of markedly different grammars are pointed by their grammars toward different types of observations and different evaluations of externally similar acts of observation, and hence are not equivalent as observers but must arrive at somewhat different views of the world. (A more formal statement of this point appears in my article of last April.) From each such unformulated and naïve world view, an explicit scientific world view may arise by a higher specialization of the same basic grammatical patterns that fathered the naïve and implicit view. Thus the world view of modern science arises by higher specialization of the basic grammar of the western Indo-European languages. Science of course was not *caused* by this grammar; it was simply colored by it. It appeared in this group of languages because of a train of historical events that stimulated commerce, measurement, manufacture, and technical invention in a quarter of the world where these languages were dominant.

The participants in a given world view are not aware of the idiomatic nature of the channels in which their talking and thinking run, and are perfectly satisfied with them, regarding them as logical inevitables. But take an outsider, a person accustomed to widely different language and culture, or even a scientist of a later era using somewhat different language of the same basic type, and not all that seems logical and inevitable to the participants in the given world view seems so to him. The reasons that officially pass current may strike him as consisting chiefly of highly idiomatic *façons de parler*. Consider the answers that were at one time given even by learned men to questions about nature: Why does water rise in a pump? Because nature abhors a vacuum. Why does water quench fire? Because water is wet or because the fiery principle and the watery principle are antithetical. Why do flames rise? Because of the lightness of the element fire. Why can one lift a stone with a

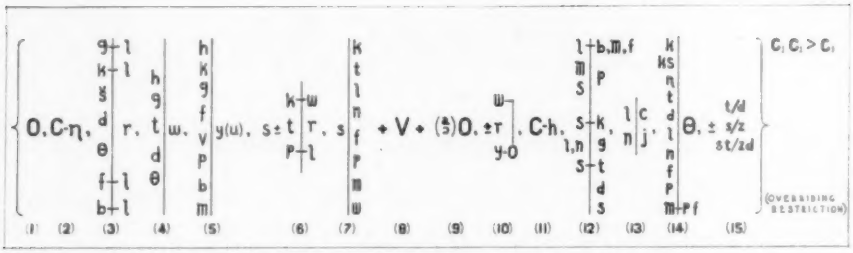


Fig. 1. Structural formula of the monosyllabic word in English (standard midwestern American). The formula can be simplified by special symbols for certain groups of letters, but this simplification would make it harder to explain. The simplest possible formula for a monosyllabic word is C+V, *and some languages actually conform to this. Polynesian has the next most simple formula,* O, C+V. *Contrast this with the intricacy of English word structure, as shown above.*

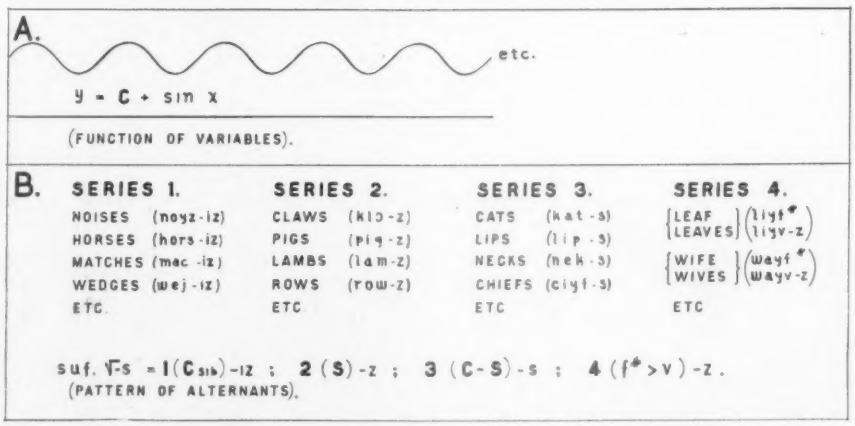
leather sucker? Because the suction draws the stone up. Why does a moth fly toward a light? Because the moth is curious or because light attracts it. If once these sentences seemed satisfying logic but today seem idiosyncrasies of a peculiar jargon, the change is not because science has discovered new facts. Science has adopted new linguistic formulations of the old facts, and now that we have become at home in the new dialect, certain traits of the old one are no longer binding upon us.

We moderns are not yet in a position to poke fun at the wiseacres of old who explained various properties of water by its wetness. The terminology which we apply to language and cultural phenomena is often of a piece with the wetness of water and nature's abhorrence of a vacuum. The researches of linguists into the ways of languages many and diverse are needed if we are to think straight and escape the errors which unconscious acceptance of our language background otherwise engenders. An increasing contribution from linguistics to the general philosophy of science is demanded by the new ways of thinking implied by those new realms of science cited at the beginning of this essay. It is needed for science's next great march into the unknown.

The situation is not likely to be aided by the philosophical and mathematical analyst who may try to exploit the field of higher linguistic symbolism with little knowledge of linguistics itself. Unfortunately the essays of most modern writers in this field suffer from this lack of apprenticeship training. To strive at higher mathematical formulas for linguistic meaning while knowing nothing correctly of the shirt-sleeve rudiments of language is to court disaster. Physics does not begin with atomic structures and cosmic rays, but with motions of ordinary gross physical objects and symbolic (mathematical) expressions for these movements. Linguistics likewise does not begin with meaning nor with the structure of logical propositions, but with the obligatory patterns made by the gross audible sounds of a given language and with certain symbolic expressions of its own for these patterns. Out of these relatively simple terms dealing with gross sound patterning are evolved the higher analytical procedures of the science, just as out of the simple experiments and mathematics concerning falling and sliding blocks of wood is evolved all the higher mathematics of physics up into quantum theory. Even the facts of sound patterning are none too simple. But they illustrate the unconscious, obligatory, background phenomena of talking as nothing else can.

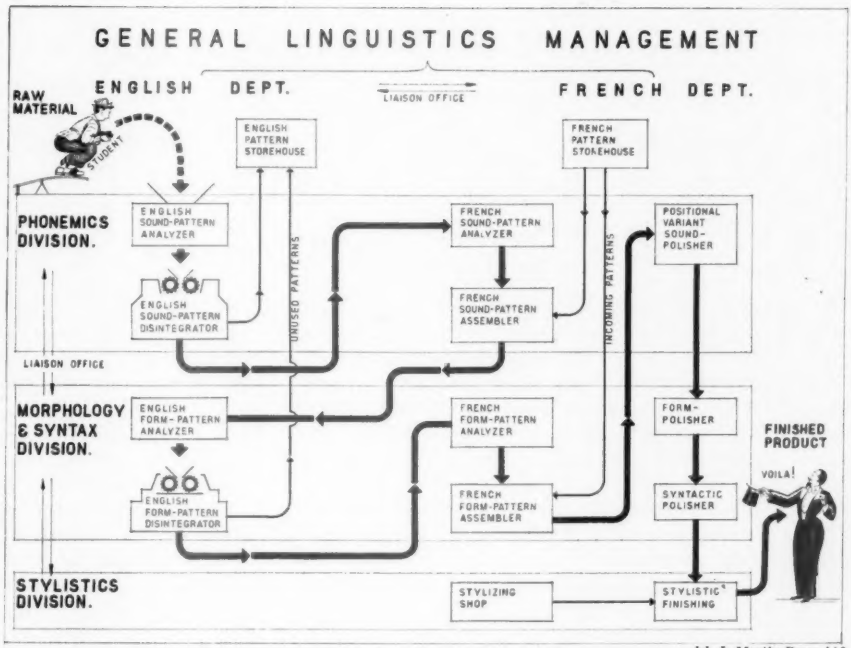
For instance, the structural formula for words of one syllable in the English language (Fig. 1) looks rather complicated; yet for a linguistic pattern it is rather simple. In the English-speaking world, every child between the ages of two and five is engaged in learning the pattern expressed by this formula, among many other formulas. By the time the child is six, the formula has become ingrained and automatic; even the little nonsense words the child makes up conform to it, exploring its possibilities but venturing not a jot beyond them. At an early age the formula becomes for the child what it is for the adult; no sequence of sounds that deviates from it can even be articulated without the greatest difficulty. New words like "blurb," nonsense words like Lewis Carroll's "mome raths," combinations intended to suggest languages of savages or animal cries, like "glub" and "squonk" — all come out of the mold of this formula. When the youth begins to learn a foreign language, he unconsciously tries to construct the syllables according to this formula. Of course it won't work; the foreign words are built to a formula of their own.

Variables and alternants: A shows by graph and by mathematical formula (equation) an interrelation of variables. B illustrates by extensible examples and by a pattern formula an interrelation of alternants. The formula means that the English suffix which is theoretically ("by root," √‾) a final s *is actualized in any given case by one of four alternants: after a sibilant-ending consonant, by* -iz; *after any sonant (vowel or consonant), by* -z; *after any voiceless (nonsonant) consonant by* -s; *except that after the special alternant* f#, *it is actualized by* -z, *the* f# *alternating to* v.



Usually the student has a terrible time. Not even knowing that a formula is back of all the trouble, he thinks his difficulty is his own fault. The frustrations and inhibitions thus set up at the start constantly block his attempts to use foreign tongues. Or else he even *hears* by the formula, so that the English combinations that he makes sound to him like real French, for instance. Then he suffers less inhibition and may become what is called a "fluent" speaker of French — bad French!

If, however, he is so fortunate as to have his elementary French taught by a theoretic linguist, he first has the patterns of the English formula explained in such a way that they become semiconscious, with the result that they lose the binding power over him which custom has given them, though they remain automatic as far as English is concerned. Then he acquires the French patterns without inner opposition, and the time for attaining command of the language is cut to a fraction (see Fig. 2). To be sure, probably no elementary French is ever taught in this way — at least not in public institutions. Years of time and millions of dollars' worth of wasted educational effort could be saved by the adoption of such methods, but men with the grounding in theoretic linguistics are as yet far too few and are chiefly in the higher institutions.



del. J. Martin Rosse, '40

Fig. 2. Flow sheet of improved process for learning French without tears. Guaranteed: no bottlenecks in production.

Let us examine the formula for the English monosyllabic word. It looks mathematical, but it isn't. It is an expression of pattern symbolics, an analytical method that grows out of linguistics and bears to linguistics a relation not unlike that of higher mathematics to physics. With such pattern formulas various operations can be performed, just as mathematical expressions can be added, multiplied, and otherwise operated with; only the operations here are not addition, multiplication, and so on, but are meanings that apply to linguistic contexts. From these operations conclusions can be drawn and experimental attacks directed intelligently at the really crucial points in the welter of data presented by the language under investigation. Usually the linguist does not need to manipulate the formulas on paper but simply performs the symbolic operations in his mind and then says: "The paradigm of Class A verbs can't have been reported right by the previous investigator"; or "Well, well, this language must have alternating stresses, though I couldn't hear them at first"; or "Funny, but *d* and *l* must be variants of the same sound in this language," and so on. Then he investigates by experimenting on a native informant and finds that the conclusion is justified. Pattern-symbolic expressions are exact, as mathematics is, but are not quantitative. They do not refer ultimately to number and dimension, as mathematics does, but to pattern and structure. Nor are they to be confused with theory of groups or with symbolic logic, though they may be in some ways akin.

Returning to the formula, the simplest part of it is the eighth term (the terms are numbered underneath), consisting of a *V* between plus signs. This means that every English word contains a vowel (not true of all languages). As the *V* is unqualified by other symbols, any one of the English vowels can occur in the monosyllabic word (not true of all syllables of the polysyllabic English word). Next we turn to the first term, which is a zero and which means that the vowel may be preceded by nothing; the word may begin with a vowel — a structure impossible in many languages. The commas between the terms mean "or." The second term is *C* minus a long-tailed *n*. This means that a word can begin with any single English consonant except one — the one linguists designate by a long-tailed *n*, which is the sound we commonly write *ng*, as in "hang." This *ng* sound is common at the ends of English words but never occurs at the beginnings. In many languages, such as Hopi, Eskimo, or Samoan, it is a common beginning for a word. Our patterns set up a terrific resistance to articulation of these foreign words beginning with *ng*, but as soon as the mechanism of producing *ng* has been explained and we learn that our inability has been due to a habitual pattern, we can place the *ng* wherever we will and can pronounce these words with the greatest of ease. The letters in the formula thus are not always equivalent to the letters by which we express our words in ordinary spelling but are unequivocal symbols such as a linguist would assign to the sounds in a regular and scientific system of spelling. (*Continued on page 80*)

Flying Up

Development of a Practical Inexpensive Helicopter Would Realize an Idea Older than Aviation

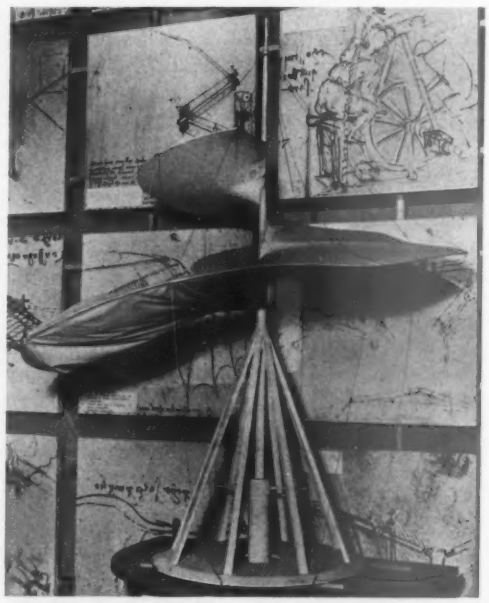
By S. Paul Johnston

MOST provocative idea in aviation today, as it has been for many years, is vertical flight in heavier-than-air machines. The picture so often painted by fiction writers and the quasi-scientific magazines — that every citizen may own an aircraft capable of taking off from and landing on his back yard or roof — awaits only the development of a practical inexpensive helicopter.

At least some of the interest has been engendered by the more or less successful development of the autogiro. The autogiro, however, is not a helicopter, nor is it capable of true vertical ascent. Some of the later autogiros with the so-called jump take-off are in a limited degree helicopters, but for short periods of time only. This does not warrant including them in the true helicopter category because during most of their flight no power is applied directly to the rotor. The possibilities of the true helicopter have attracted the attention of a number of our outstanding airplane designers. Success is not yet, but there are indications that, given a reasonable amount of effort, the next few years may see a practical machine developed.

The idea is possibly older than aviation itself. Da Vinci gave the problem considerable thought. His notebooks indicate that he built small models which flew successfully, and that he made plans for a machine some ninety-six feet in diameter with a linen-covered framework of iron and bamboo. He never built it because he had no power available to drive it. But the fundamental concept goes back farther than that. We find reference in ancient oriental literature to the so-called Chinese Top, probably the first heavier-than-air device actually to fly. No one knows exactly how long ago it originated, but as a toy it appeared in Europe shortly after the first balloon flight of the Montgolfiers in 1783. It was exhibited as a scientific curiosity before the French Académie des Sciences by Launoy and Bienvenu in 1784. Sir George Cayley, experimenting a few years later with various flying machines in England, built several modifications of the Chinese Top. One of his machines, according to his own notes, rose as much as ninety feet in the air. Sir George made some sketches for a full-size steam-driven helicopter, which in some respects was not unlike the successful Focke-Achgelis machine of 1937. There is no indication, however, that he ever carried the idea beyond the model stage.

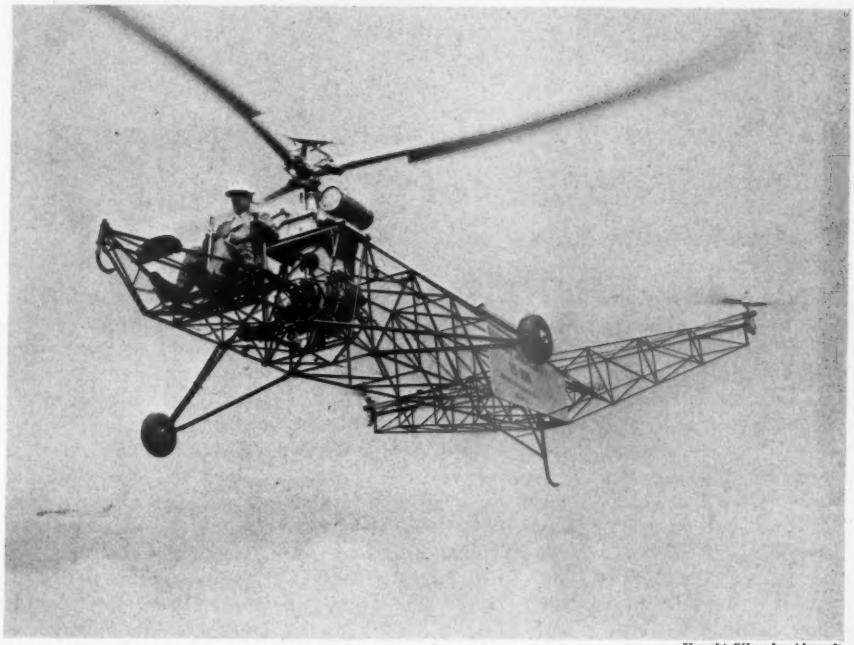
A number of helicopter proposals and models were put on display in the exhibition of the Aeronautical Society of Great Britain at London in 1868. Among them were designs from the fertile imagination of Felix Tournachon, otherwise known as A. Nadar. None of these had any practical value whatever, but they did stimulate popular imagination to the point that many curious notions for "aerial steamers" began to appear in the public prints, most of them definitely of the Jules Verne variety. A number of experimental models were actually constructed, but there is no account of any real success until 1878 when Enrico Forlanini, an Italian professor of civil engineering, built a model that weighed almost eight pounds and was driven by a one-quarter-horsepower steam engine. It succeeded in hoisting itself over forty feet in flights of about twenty seconds.



Scale model of Leonardo da Vinci's design for an "aerial screw," which heralded the helicopter. To furnish motive power, he designed a spring-driven mechanism much like modern clockwork. The model is shown, together with other examples of the famous painter-scientist's work in aeronautics, as part of an exhibition of his scientific achievements now at the New York Museum of Science and Industry.

Several experimenters in the late 1800's began to use the then newly developed electric motor to test helicopter ideas. Gustav Trouve exhibited an electric helicopter before the French scientific societies of 1887 and 1888. He used a small electric motor of remarkably light weight which flew the model successfully — but not with the necessary power supply on board. Current was furnished to the motor through a pair of trailing wires, a feature which undoubtedly lent considerable stability to the models in flight. Trouve then proposed a large machine of the same type for military purposes, anticipating Von Kármán and Petroczy by over thirty years, but the project was not carried out.

Maurice Léger, working in Monaco in 1905, built an experimental helicopter consisting



Vought-Sikorsky Aircraft

Igor Sikorsky's helicopter in flight, with the inventor at the controls

of two 20-foot counterrotating airscrews, electrically driven. The motors, however, stayed on the ground, driving the propellers through flexible shafting. This setup was obviously not intended to be flown, but it was used to develop certain fundamental data on the airscrew as a listing device. Léger's results show agreement with current theory.

In 1907 a Frenchman, Paul Cornu, built a full-scale helicopter that was the first to have any real promise of actually flying. His two 20-foot lifting screws were mounted on outriggers in the modern manner. They were driven by a twenty-four-horsepower Antoinette airplane engine. The machine allegedly got into the air for a few seconds at a time but once off the ground proved quite uncontrollable.

Thomas Edison, in America, became interested in the problem and made tests on vertically acting airscrews driven by electric motors. He mounted the machines on platform scales to measure the amount of lift developed, but never succeeded in getting off the ground. He was convinced of the ultimate success of the helicopter and, when questioned about airplanes and helicopters in 1908, said, "Whatever progress the airplane might make, the helicopter will come to be taken up by the advanced students of aeronautics." Today, Mr. Edison's statement of thirty-odd years ago seems to have been prophetic. After many years in which the airplane has held the center of the stage and has been developed to a remarkable degree, interest is being revived in the possibilities of the helicopter. Several full-scale projects are now under way, some of them by men who have previously made names for themselves in the field of airplane design.

The case of Igor Sikorsky illustrates the point. Back in 1908, when he was beginning to turn his thoughts to flying, the helicopter seemed to him the most logical thing to try first. He lacked money to buy an engine, but his sister, Olga, came to his assistance and supplied him with enough to buy a twenty-five-horsepower three-cylinder Anzani motor. Young Sikorsky had been to Paris early in 1909 and had seen this engine used successfully in a number of French airplanes.

His first helicopter did not prove much. It had two two-bladed concentric lifting propellers — the upper sixteen feet in diameter, the lower sixteen and one-half feet in diameter — rotating in opposite directions at 160 revolutions a minute. Late in the summer of 1909 he was ready to test it, but it was apparent from the first that the machine would never fly. It vibrated badly and showed little signs of lifting itself from the ground. Nothing daunted, Sikorsky spent the winter with a new design, which was ready in the spring of 1910. This time the results were somewhat better, for the machine lifted its own weight of 400 pounds, but could not take care of pilots or passengers. Try as he would he could not see how to remedy this situation. Besides, he was becoming increasingly interested in airplane design; so he put the helicopter idea on the shelf for almost thirty years.

Today, after many years of outstanding success as an airplane designer, beginning with the multiengined machines he built for the Czar of the Russias in 1916, down to the great clippers that have been flying Pan-American Airways' Pacific and Atlantic routes, Sikorsky has again turned his attention, this time with some success, to the problem of vertical flight. Last April, after many months of secret experimentation in his plant at Bridgeport, Connecticut, he made the first public demonstration of a helicopter that has the earmarks of practicality. At first the machine was underpowered. By overspeeding the motor on the ground it was possible to make hops of short duration, and it was enough to prove that the machine could be flown and controlled. After a long series of tests a ninety-horsepower engine was installed and performance was greatly improved. By mid-July a number of satisfactory flights had been made, one of them being of fifteen minutes' duration, which, as far as is known, is the longest flight ever made in the United States with a direct-lift machine. Sikorsky reported the performance and control characteristics as satisfactory and extremely promising. He could lift the machine directly off the (*Continued on page 83*)

Boring History

Ancient Workers Drove Holes with Flint Drills and Core Drills and Pump, Strap, and Bow Drills

By Leroy L. Thwing

TO argue that the rivet is more important than the rivet hole or that the shaft is more important than the bearing in which it turns, would be a waste of time, but it could be argued that holes are more nearly fundamental to the mechanical arts than are either rivets or shafts. If we were unable to drill holes, everything would have to be made in one piece unless it were mortised, glued, or welded together. A great advance has been made in welding technique in the past twenty years, but, generally speaking, our structures, machinery, and furniture are made of various parts which are riveted, bolted, doweled, screwed, or nailed together. Rivet holes are made with punches and drills; holes in wood, with bits and augers. Wood screws and nails, however, are more self-sufficient, since they make their own holes as they go along.

*Fig. 1. Drill point **

If holes are of such importance, we should naturally expect that the ability to make them would be very ancient, as, in fact, it is. Flint borers hundreds of thousands of years old are found among the oldest of the chipped stone tools of prehistoric man. Fifty thousand years ago the flint drill was so well developed that there was little subsequent improvement except in methods of rotation. The earliest chipped stone tools were simple and were used indiscriminately as axes, chisels, and scrapers, but they could not be used to drill holes. The flint drill was probably the first special-purpose tool developed by primitive man. A by-product of this development was the fire drill, which may have been the device with which man first made fire at will.

The first flint drill points were short and blunt, but over a period of hundreds of thousands of years they developed into long flint borers. They were strictly hand tools at first, and the amount of rotation given them was limited to a twist of the wrist. The drill point illustrated in Fig. 1 is typical. Its use is restricted to the softer materials, such as shells, bone, and so on, and the holes would be tapering.

In addition to flint drill points, primitive men must have had some other means of drilling hard materials, as there are many existing examples of long, small, smooth holes drilled in stone as hard as flint itself. In the National Museum in Washington are a number of beads found in Mississippi. They are made of red jasper, which is too hard to be scratched by any modern steel tool. In the American Museum of Natural History in New York City are hundreds of drum-shaped beads about a quarter of an inch in diameter, each pierced with a hole 1/32 of an inch in diameter; some of these are a quarter of an inch long. These beads are made of turquoise matrix, which is just a little softer than hard steel. They came from California and are about a thousand years old. The men who drilled them had no metals whatsoever. I have examined many of these beads; the holes are smooth, round, and not noticeably bellmouthed. The beads are truly cylindrical within less than one-thousandth of an inch by micrometer and run true on the hole. These are typical examples of primitive drilling of small holes, but in other museums in other parts of the world are larger holes, such as those in banner stones and in stone axes. In Egypt, moreover, are large holes cleanly drilled through — or into — the solid rock.

Fig. 2. Hole and core

There are plausible explanations and considerable evidence of the methods used to drill such holes as the foregoing, but it is not easy to explain the method used to drill certain beads on view in the American Museum of Natural History. These beads appear to be made of clay, but they are not; they are made of stone. Each is about four inches long, *crescent shaped*, and pierced from end to end with an eighth-inch hole. Since this hole is not straight (you cannot see light through it), the observer's first thought is that the hole was drilled along the axis of the bead, on the arc of a circle — a most difficult, if not impossible, task. A more likely explanation is that holes were drilled from each end and met in the middle. What seems to be a shoulder at the meeting point can be felt with a wire. This failure of the drill holes to meet head on simplifies the problem somewhat, but anyone who has tried by hand to drill holes from each end of a long wooden cylinder and have them meet in the

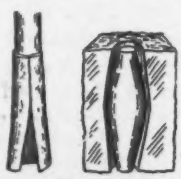


Fig. 3. Tubular drill, spread

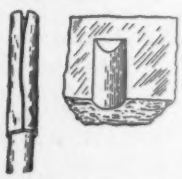


Fig. 4. Tubular drill, unspread

*All illustrations except Fig. 2 are from the Report of the United States National Museum for 1894. Figure 2 is from *Die Technik der Vorzeit, der geschichtlichen Zeit und der Naturvölker* by F. M. Feldhaus.

Fig. 5. Palm method

middle can testify to the difficulty of this operation. The makers of wooden pipe — the pump makers and blockmakers of the Eighteenth Century — did not attempt it if they could avoid it. How the Indians of California could have drilled such holes is a mystery. In the words of a curator of the museum: ". . . The question still remains as to what they used for drilling such a long, small-diameter hole."

In the Dark Ages the ancients were believed to have had the secret of softening stone, which enabled them to drill holes in precious stones and then harden the stones again. This was one of the so-called lost arts, such as the art of making malleable glass, about which Wendell Phillips used to lecture. Unless we subscribe to the ancient belief, some sort of grinding or abrasive process seems to have been the only possible method for drilling such small, smooth holes as those of the museum beads.

Grinding processes are very old. The tools and ornaments of the Neolithic, or Polished Stone, Age were first roughed out by being chipped and then were finished by being ground and polished. The wampum of the American Indian was made of shells or other animal material shaped by being rubbed on a piece of sandstone, drilled, and strung on a thong. The wampum holes were probably drilled with flint borers, but holes in banner stones and in jasper beads must have been drilled by some kind of grinding process. Archaeologists suggest that the smallest holes were drilled with splinters rolled in sand, and the larger holes, either with bigger solid pieces of wood or with core drills. They may have deduced the use of the wooden lap, but ample evidence of prehistoric core drilling exists. In core drilling, either ancient or modern, the edge of a tube is charged with an abrasive — in modern practice it is set with diamonds — and rotated in contact with the stone to be drilled, in which it cuts a circular groove and leaves a solid cylindrical core, which either drops out or is broken off. The core drill is a sort of rotary biscuit cutter, in which the biscuit is the core. Figure 2 shows an uncompleted hole and the core from another hole. Figures 3 and 4 illustrate the method used. In Fig. 3 the tube has spread, resulting in a hole that is larger in the middle than at the outside. Stone axheads pierced with such holes must have been drilled in this way. These illustrations indicate the use of metals. Our western Indians had copper and the Egyptians had bronze in the earliest historical times; furthermore, a hollow stem or twig can be used for small holes.

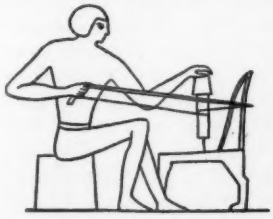


Fig. 9. Egyptian bow drill

Fig. 7. Eskimo using strap drill

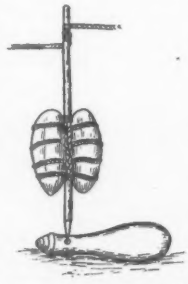


Fig. 8. New Zealand drill

A complete reconstruction of the various drilling methods of prehistoric men is evidently impossible, but we have many examples of their work and also a knowledge of the procedures used by primitive races today. The actual tools were simple, but methods and appliances to rotate them developed slowly. The first step was to mount the drill in or on a wooden shaft or drill holder. This could be rolled between the palms or on the thigh. That the palm method is not entirely conjectural is shown in a Mexican wall painting (Fig. 5). Two helpers are holding a log while it is being drilled. The artist may have exaggerated the size of the drill and the chips, but the method is clear. Figure 6 illustrates the thigh method used by the Indians to drill shells for wampum.

Fig. 6. Thigh method

Both these methods have their limitations; little speed, power, or pressure can be applied to the work. Although not absolutely necessary for small holes, greater speed would be an advantage, and more power would be needed for larger holes. After some probably lengthy period of time, it was discovered in various parts of the world that by wrapping a thong around the drillshaft, a man could rotate the drill in the manner shown in Fig. 7. This was a great improvement, but as a one-man device, it required the use of both hands, both legs, and the teeth. The next improvement was to have the drill rotated by one or more other men. This latter method was used as early as 900 B.C. to drill large holes in wood. We know this fact because Homer, in the *Odyssey*, describes the method used in his day for drilling treenail holes in ship timber. When Ulysses tells how he and his men put out the single eye of the Cyclops, he says: "I thrust the stake into the embers until it became hot . . . and some of the others thrust it into his eye, while I standing above, turned it round and round, as when a man bores a ship's timber with a drill, having bound it around with a thong, while others laying hold on either side turn it constantly. . . ." It is not difficult to reconstruct this scene: The master driller stands and holds the drillshaft erect in a socket at the top. A thong is given a turn or two around the shaft, and two helpers pull alternately, rotating the shaft until a hole is "worried" through the timber. Scientists call this a strap drill (Fig. 8).

A development of the strap drill is the bow drill, the earliest types of which did not use the elastic bow to keep the cord tight. They used rigid rods with handles and drew the cords tight, as shown in Fig. 9, taken from an Egyptian wall painting. This rotating device has been widely used over a long period of time. Until quite re- (*Continued on page 86*)

Fig. 10. Pump drill

Motor Necrology

If Drivers Cannot Control Cars, Ways of Controlling Drivers Must Be Considered

By John W. Meader

NO one has yet been able to make the people of the United States appreciate the enormity of their motor-vehicle accident record. No thought being entertained, therefore, of convincing a majority that the affair is serious, the situation is herein sketched very briefly.

The number of persons killed in motorcar accidents in the United States in July, August, and September — 9,190, according to the National Safety Council — exceeded British civilian deaths resulting from air bombings from the time heavy fighting began through September — 8,365, as reported to the Commons by Winston Churchill. Our seasonal peak of motor accidents was still to come. We have dispatched more people in motor accidents since 1933 than the number of soldiers killed or dead of wounds in all the wars we have fought. Imagine the complete annihilation each year of a city of something over 32,000 population — a city like Norwalk, Conn., Elgin, Ill., or Santa Barbara, Calif. — to get an idea of the annual death toll. Or envision a recurring catastrophe which left every man, woman, and child in Los Angeles more or less fatally injured, to see the human damage — no matter about the loss of property.

But the facts will not impress. At least, they have not done so; year after year we go on laying out upwards of 30,000 corpses and a million lesser derelicts. Yet the few who are curious about the whys and wherefores of this ghoulish phase of Americana may be interested in a look at the accident record and may want to consider what can be done toward reducing the melancholy totals. Those who have combed the ground with greatest care are sure they know what is needed and will guarantee with their professional reputations a 50 per cent reduction in automobile deaths, starting almost immediately!

There is really no such thing as an accident in the sense of something untoward just happening in an inscrutable, uncontrollable fashion. On the whole, either a car is pushed and steered into a collision or clear proof exists of failure to divert the car from an impending collision by a change in course or speed or both. In either event there is a failure of the human portion of the control mechanism. A detailed knowledge of this mechanism, regarded as a whole, is essential for a proper understanding of motor-accident causes.

The control of a car depends upon a set of environmental conditions. The width of the road, the nature of the margins, the grade, curvature, and surface, the obstacles present *or presentable*, the *speed* of the vehicle, its characteristics of acceleration, deceleration, and stability — these are the principal physical circumstances which determine absolutely whether a collision may or may not occur. Knowledge of these determining conditions, impaired or impeded in transmission by fog, rain, dirty windshield, noise level, and so on, reaches an attentive driver through his sensory perceptions, most important of which is his vision. Now the driver goes to work. The information received must be sorted, weighed, and assembled into a conclusion and, if necessary, a purpose of action. Then come the driver's motor responses, whereby the car controls are actuated. The car proceeds to do exactly what he *made* it do, although that may not be what he *wanted* it to do.

If accidents are to be precluded, no break may occur in this long chain which begins with highway conditions and ends with the coefficient of friction of rubber on concrete. Obviously, a continuous operating load is thrown on the driver — the weakest link of the chain. There is no time at any average speed for all his mental operations to be on a conscious plane. The fumblings and labored thought processes of the beginner were long since grooved into habit, for better or for worse. Naturally, no engineer would deliberately specify so unreliable a piece of machinery as a human being for so complicated a task as the driver must perform. The engineer can at most facilitate the mechanical operations of the control process, but that is all, and that is not enough.

A careful study of the control process shows dozens of opportunities of accident prevention through purely mechanical changes. To cite some of the most flagrant examples: No good excuse can be offered for the extreme rake given to windshields in current designs; or for small windshields; or for bulky corner posts in the field of vision; or for a three-passenger driver's seat. At the other end of the control chain, there is not much excuse, in the present state of the art, for cars which are directionally unstable in being braked from high speeds, as many cars are; or for the use of windbreaks, in the form of fake streamline tinware, which effectually prevent brake cooling. Many other little faults could be pointed out, but no amount of mechanical change and improvement, as such, will do more than make a dent in the accident problem. For real progress, we must turn to the driver. The success of the control mechanism depends so heavily on him that progress will be achieved more readily through an objective study of his characteristics than through research of any other kind. Presumptive proof of this statement is shown in the fact that obsolete cars are much less liable to serious accidents than are the most recent products.

The driver plays a dual role: He is the proud owner, or at least the one who directs the general course and speed of the vehicle. He would like to get where he is going in

no time at all. But he is also the operator. As such he will have acquired some sense of the car's and his own limitations and, through practice, more or less facility in the operating job. He is predisposed, however, to appreciate the car's limitations more clearly than his own; the roles of director and operator almost invariably conflict. Reason struggles with emotion. As a result of fatigue or alcohol, reason weakens and emotion becomes increasingly insistent. Only when the operator exerts a conscious self-restraint, continuously adjusted to the conditions of the moment, can he be said to have the possibility of collision under reasonable control. It is true that automobile drivers as a whole are constitutionally capable of exercising sufficient emotional restraint under all varieties of conditions which they meet, but only a very small number of supercharged drivers is needed to ring up the grisly figures.

The paramount physiological shortcoming is an inability to judge speed accurately in a quiet, closed car. Without a windshield the pressure (of still air) against the driver's face would vary almost directly in proportion to the shortest stopping distance *after* bráke application. Behind the windshield of a closed car he has practically nothing but his visual sense as a guide.

The human eye is in some respects a very crude instrument. It has little resolving power and is handicapped with a blind spot and a pronounced time lag to changes in the field. The visual sense works at a special disadvantage when it must translate a change in the size of the image (as of an obstruction) into an estimate of relative speed. We are at great pains in the control of naval gunfire to correct for these deficiencies, yet we accept them in civil life in the control of an instrument with a much more impressive lethal record. The speedometer of an automobile is of very little help. It is not, and should not be, in the field of vision. Although all speedometers are geared somewhat fast, the standard linear dial grossly distorts the vital implications of the speed registered. Only a scale proportioned to the *square* of the speed with adjustment for reaction time could approximate the true situation. A scale calibrated in danger units would horrify many automobilists.

We do not have to look far to find that excessive speed is the principal cause of motor-vehicle deaths. One of the best bits of evidence is the surprisingly uniform total of dismal consequence during recent years, when hundreds of agencies have been moving heaven and earth to reduce the deaths even as car speeds have been going up and up. The following figures are those of the National Safety Council.

Year	*Number of Deaths*	*Number of Deaths per 100,000 Population*
1928	27,996	23.3
1929	31,215	25.7
1930	32,929	26.7
1931	33,675	27.1
1932	29,451	23.6
1933	31,363	24.9
1934	36,101	28.5
1935	36,369	28.5
1936	38,089	29.7
1937	39,643	30.7
1938	32,582	25.0
1939	32,600	24.9

The 1940 figure, from preliminary indications, will show that fatalities are again on the way up. If, as some argue, the trend in the number of deaths per vehicle mile has been declining, this fact would mean only that we now go farther, but not longer, to meet our fate. No significant change has taken place in the total of deaths relative to the number of motor vehicles in use.

During the past decade a tremendous cumulative effort has been made to bring down the fatality rate. We have better roads, better (*Continued on page 89*)

Wide World Photos

Mobility at rest — a modern parking lot

Net Returns from the Banks

Otter Trawls in the Modern Manner Gather Tons of Fish, and Quick-Freezing Methods Balance the Nation's Markets

By Richard Hallet

I TOLD a friend that I was going on a trip in the trawler *Storm*, and he said at once: "The *Storm* — I remember reading about her; she's the fisherman with shower baths."

More than that, on board the *Storm* the men have cantaloupe for breakfast and strawberries in season; but with all these handicaps she catches plenty of fish. It's hard to say where the line should be drawn against luxury on the sea. I did hear tell of a trawler captain who smoked perfumed cigarettes and dashed cologne on his handkerchief. That was just the last straw, and he had to go redfishing because the codfish smelled him coming.

The *Storm* hasn't the cologne handicap. She's a steel-built ship — 143 net tons, 144 feet over all — and she can carry 350,000 pounds of fish in her nickel-plated holds, which are kept cool with chipped ice and an ammonia coil. The *Storm* is the last word in the science of catching fish. Her six-cylinder, heavy-duty, self-lubricating, McIntosh and Seymour Diesel engine is a floating powerhouse big enough to run a small city. A fan throws into her fish holds 1,800 cubic feet of cold air a minute, right off that ammonia coil. Her radio gives her bearings and keeps her up to the minute on market conditions. Her fathometer flashes soundings which enable her to stay where the fish are thickest. Her electric winches can pick up 6,000 pounds of fish in one grab.

But here the precision stops short. We have come to the net and the sea bottom. There is no device that whispers to fish and tells them to go into the net. That's a blind drag — either the fish go in or they go clear. The *Storm's* nets are made in Grimsby, England. They are 150 feet long and 78 feet from wing tip to wing tip. The belly, or bottom, meshes of the net are sheathed with a patchwork of cowskins, which protect it against jagged rocks. The lower jaw of the net is a wire cable, on which are threaded wooden wheels cut from rounds of trees. These wheels roll that jaw over obstructions and look like a giant wooden necklace. The top jaw is held up by metal buoys seized to the headrope.

The wings which usher the fish into this huge blind mouth are stretched wide by wooden "doors" which are steel shod and are so attached to the main dragging wires that they fly kitewise, opening the net to its fullest extent at a towing speed of from two to three miles an hour. These doors grind over rocks and dip into gullies; the wooden wheels, so waterlogged that one wheel is a lift for a strong man, roll forward; the fish swim in and ball up in the cod end, which is the very end of the net, in shape like a giant finger cot of four-strand twine. A swordfish may slash his way out of this net. Even a shark has it in him to bull his way out; his nose is delicate, however, and dislikes the feel of twine, so that an occasional shark does come up with the rest of the catch. But cod and haddock, once they venture in, have a poor show for their lives.

The *Storm* wastes no time. She came into the South Boston fish pier on a Tuesday morning, and by Wednesday at 1:00 P.M., when I boarded her, she was off again on her 210-mile journey to the northeast peak of Georges Shoal. This was in July. In winter, the *Storm* may go as far east as the Sable Island, or Western, Bank, or even to Banquereau, but in summer the captain is mistrustful of fish caught too far east. It makes too long a haul — nearer a fourteen- than an eight-day trip.

Watches were set: At sea, the *Storm's* men go six hours on and six hours off; once on the grounds, the ship fishes continuously, day and night. She tows her net for an hour and ten minutes — sometimes for as long as an hour and a half — and so averages ten to twelve and sometimes fourteen bags of fish for the twenty-four hours. Three thousand to five thousand pounds of fish make an average summer bag. I believe the record bag was forty thousand pounds.

Our first set was made at about ten o'clock in the morning on Georges Bank. Over went the net on the starboard side; after it, with a splash, went the 1,800-pound doors. Next, the main towing wires were paid out. The *Storm* circled and streamed her net, then altered her course to bring the towing wires more aft. A big hook grappled the wires together, and the winch brought them in against the ship's side and prisoned them in the knockout block fixed at the stern rail. There the two wires were not an inch apart, but they led down to the two doors. The towing motion forces the doors in opposite directions, and opens wide the wings of the net, to "welcome little fishes in with gently smiling jaws."

The net, crawling on the bottom, must look rather like a dragonfly with a very wide mouth. But there's no looking at it. From the *Storm's* bridge, there's no telling at what spot or spots the fish enter. Lately the Germans are said to have a gadget that registers increasing pressure on the wires as the net fills. This instrument should enable the ship to turn round and round inside a spot of

General Seafoods Corporation

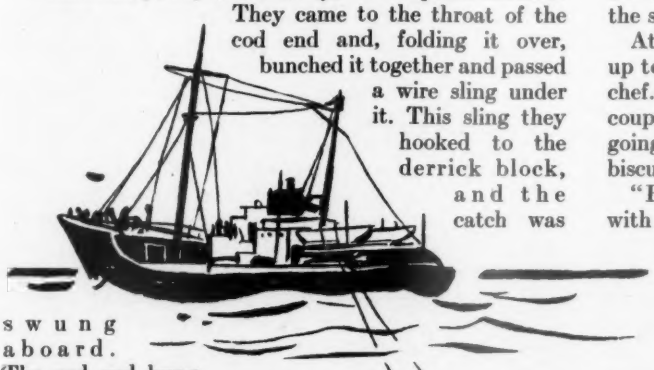
When this Diesel-powered steel-built trawler returns to Boston from the Georges Bank, her nickel-plated holds will carry approximately three hundred thousand pounds of fish, netted by the technique shown in the opposite sketch of a trawl in use. Note the "door" on the net end of each towing wire. Weighing almost a ton each, these doors keep open the entrance to the fish's finish.

fish, keeping always at the point of greatest concentration. The British claim that they can use the fathometer to mark fish. This statement sounds reasonable, for if you can bounce an echo off the bed of the ocean, why not bounce it off the backs of fish if they run close enough together? Some fish do school so close that they clash and score and scar each other's sides. But I do not give this story on my own authority.

After dragging an hour and ten minutes, Captain Michael Shea of the *Storm* rang his engines astern, and the towing watch jumped into oilskins. They forced the pin out of the patent knockout block. The towing wires sprang apart, and winches under the pilothouse reeled them in.

The *Storm* seemed to brace herself, like a cow pony on the western plains whose rider has got his lariat around a steer's hind hoof. The boat circled to come round to leeward of the net. Then the doors came out of the sea and banged against the gallows. These frames, inverted steel U's, are fixed, one forward and one aft, against the *Storm's* rail and from them hang the sheaves through which the towing wires run inboard to the winches. After the doors, came the ground cables attached to the wings of the net. Finally the cod end bounced up, shining white with the cowskins on its belly. The towing watch clustered amidships, hauling the net over the rail. They swayed back and forth, dragging at the meshes with iron hooks; the net came harder and harder; they waited for a roll of the ship to gain another foot.

"Haul away, boys, haul away," the captain shouted. They came to the throat of the cod end and, folding it over, bunched it together and passed a wire sling under it. This sling they hooked to the derrick block, and the catch was swung aboard.



The cod end hung over one of the four shallow bins on the foredeck. One man pulled the cod-end knot in the very bottom of the bag. This is a crafty knot that unwinds slowly enough to let the man opening the bottom of the net get away from an avalanche of cold fish. It's no joke to have 7,000 or 8,000 pounds of cod and haddock rain down on your devoted head. In winter, when seas are rough, a man may slip and fall, and find himself buried under live fish. Then his mates must turn to and fishfork him out.

"Cod are worse than haddock for falling on a man's head," Captain Shea maintained. "Come at you like a ton of rocks."

I couldn't think that even the same weight of haddock would be like an eider-down quilt; but cod, he said, have more spring in their heels.

I looked at the contents of the bin. Certainly the drag was not selective; as usual, it was a democratic haul, with cod and haddock and pollack rubbing scales with sculpins and the hideous monkfish; with catfish and butterfish and breams and scallops and clams and now and then a lobster. Shrimps and crabs and starfish and sand dollars lay scattered among bigger fish; and now and then there was a rusted anchor. It wouldn't have been surprising to find Long John Silver's wooden leg at the bottom of the heap.

The watch on deck disposed of the catch. They forked overboard the undesirables: the sculpins, the monkfish, and the skates. Skates are the worst; if they are too thick, they drive the money fish away, just as dogfish blast the hopes of line fishermen. In Europe, skates themselves are money fish and bring at least half the price of good cod; not so with us. Two men ripped the fish with quick motions of the knife — the whetstone is ever handy — and two more gutted them and threw them into a bin amidships, whence, after a sluicing with the salt water hose, they were forked down into the refrigerated hold. Both ripping and gutting are hard work, especially in winter when men sometimes get "overgrasp," a torturing cramp of the muscles in the forearm.

About this time the trawler *Boston* went past us, homeward bound. Tomorrow her fish would be filleted and headed for the West. Twenty years ago hardly a fish that swims in salt water was eaten two hundred miles inland; now the Dust Bowl receives the yield of the North Atlantic in good condition, as it receives also the swordfish exported to it by the Japanese.

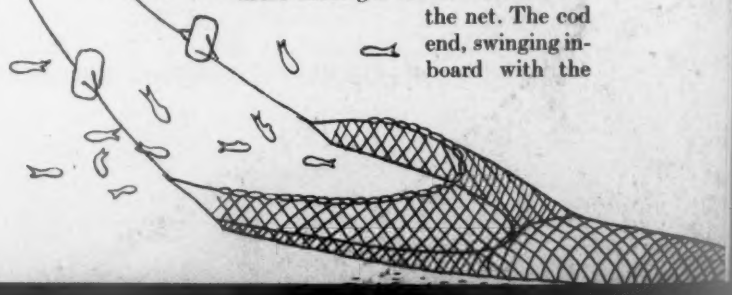
At five-thirty in the afternoon, the watch below came up to eat. The *Storm* has a spotless galley and a skilled chef. The watch pitched in with zeal, beginning with a couple of helpings of fish chowder to lay a foundation, going on to meat and potatoes with vegetables and hot biscuits, and topping off with pies and ice cream.

"Bending and twisting and hauling the way they do, with all those side motions," the chef said to me, "the men can wear down a lot of grub in a day's work."

At least it's their own grub and not the company's. As the lay now is, the company furnishes ship and fishing gear, and the men buy fuel, food, ice, and even their own blankets. It makes as much difference to the men as to the company whether haddock is four or four and a half cents a pound when they come into port after a session out on the fishing grounds. Also, it's an advantage to the men to be shipping out with a high-line captain, such as Captain Shea. Mike Shea knew where he was, "like walking in the street." Having long haunted this neighborhood, he had a kind of fathometer inside him that told him when he was getting on fish. He had a nose for fish and never lost that feeling that the next bag would be a "floater."

"First he smells them out, and then he speaks to them and tells them where to stick their noses," Joe Flynn said.

And that would be, naturally, into the bag. Bag by bag we filled the holds, and more and more moss got into the meshes of the net. The cod end, swinging inboard with the



hair wearing more and more off its cowskin belly, looked half like a decapitated whale and half like a woolly sheep. Other trawlers began to heave in sight, their sixth sense telling them that the *Storm* was getting good bags. Certainly some of the captain's friends knew, for he had picked out a ring of truthful men who were willing to tell him the situation exactly as it was. They exchanged "hails" by radio, truthfully speaking the weight of each bag as it came in. They were not like certain other skippers who might be over a spot of fish so thick that a man couldn't slide between their backs, and still radio, "No fish." Or, worse yet, bring up nothing but mud and shells, signal, "Fishing's fine here" — and steam away.

There came a lean bag of fish.

"Ah, the things have gone some place," Captain Shea said darkly. "We must be too far east. I'll have to feel around a bit and try and get on a few."

Fish shift their grounds between drags, for reasons best known to themselves. And they range far. On the Georges Bank, cod have been picked up with French hooks in their mouths from the Grand Bank, a thousand miles away. The Grand Bank is still an international city of the sea, even as in the days of schooner and dory fishing. The British have trawlers there, and so have the Danes, the French, and the Spaniards. I have heard of a late type of Spanish trawler with double decks, including a shelter deck for gutting the fish. Spaniards always did run to galleons.

One man in our crew, Danny Houghton, had fished the whole continental shelf from Iceland to Morocco and from the Barents Sea to the west of Scotland, Rockall, and the southwest of Ireland, where trawlers fish in waters all but fathomless. Once Danny was frozen into Iceland's ice pack. This was just after the last war, and the government had taken away the ship's radio. Hence the ship had no way to cry out to the land that the ice had pinched her in, and there she lay for months. The fish in her holds turned pink, and at last her men ate the very rats — which are no part of the *Storm's* diet.

The North Sea has been overfished, but our American Banks still yield well. The trawlers may of course depopulate them in the end. I have heard it said that the otter trawl threatens extinction of fish by hauling their feed off the grounds. The dragnet, so the argument goes, tears loose and crushes the marine growths — the sponges, sea moss, anemones, mussels, crabs, shrimps, sea pumpkins, worms, and microscopic plants — on which the food fish live. It is hard, however, to see what harm, actually, is done to these food supplies by the dragnet. An area of eighty acres is swept in a drag of an hour and twenty minutes, and on the whole the fish come up fairly clean. Sometimes there may be a bushel of trash — at most four or five bushels — but this is shoveled right back again. And it is certainly not true that the otter trawl destroys the spawn of food fish, since on the New England Coast the eggs of all important food fish — except herring — are pelagic and float at or near the surface.

It is true, however, that the trawls take smaller fish than the old Gloucestermen took and that this is a threat to the population of the Banks. In the North Sea, nets have been designed with windows or frames in the cod end, to hold certain meshes open at all times and allow smaller fish to escape. In this country, there is a movement to enlarge the mesh of the net, but whether bigger meshes will turn the trick is still a question. Towing drags the meshes out flat and prevents escape until the fish is at the surface, and by then he is poke blowed. Often I saw stray cod or haddock floating belly up and trying with ineffectual wriggles to work the excess air out of them. Now and then a puff of air escaped in silver bubbles.

"Haddock are better than cod at regaining their depths," Captain Shea said. "Pick up one of these fish now, and squeeze him in your two hands and throw him back. Down he'll go like a cobblestone."

Winter fishing on a trawler is better than summer fishing but entails more hardship. There's more of slambanging and rolling and jerking, more chance of a dangerous fall, more chance, too, of ruining the net. Brine ice molds itself in fantastic corrugations on the ship's rails, shrouds, masts, booms, and winches. The skipper may have to punch out the pilothouse windows to see ahead, ice forms so fast on the glass. The ship develops a top-heavy roll, and the crew are forced to pinch up their mattresses, with life preservers wedged under the edges, to keep from rolling out in their sleep.

Even so, they do roll out sometimes. George Greek of the *Storm* was pitched out of an upper bunk on the port side and dropped, mattress and all, into a lower bunk on the starboard side of the fo'c'stle. Flying through the air, he woke up enough to hug his mattress tight, but it got on top and he broke the fall for it by coming down across the edge of the bunk and breaking a couple of ribs.

The *Storm* brought into the South Boston pier a little under three hundred thousand pounds of fish, caught in seven days. Most of this catch was going to be filleted and quick frozen with all speed. A revolution in methods has taken place in the last decade. Before that time, nothing was more strongly rooted than the popular prejudice against frozen fish — a prejudice resulting from the custom that dealers had of freezing stale fish and doing so by the slow-freezing process. After much experimenting, various quick-freezing methods were found to be better than slow freezing.

First, however, unsanitary conditions in the industry had to be cleaned up, to guard against bacterial infection on the ship, as well as on the wharves, in the markets, and in the fish-packing plants. As disinfectants, chlorinated sea water and sodium hypochlorite solutions have demonstrated their value. Water from the outer harbor, chlorinated to about seven parts per million on the suction side of the pump, is used to wash the fish on the receiving wharf and is also sprayed on the fish fillets before they enter the brining machine. The antiseptic strength of this disinfectant greatly reduces the number of bacteria on the surface of the fish. The floors and machines of the filleting plant are also frequently flushed with this chlorinated sea water and are scrubbed at night with a strong hypochlorite solution. There is still a genuine need for better sanitation on the fishing vessels themselves. It is now calculated that disinfecting methods reduce the bacterial count of the fish passing through the plant (*Continued on page 88*)

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

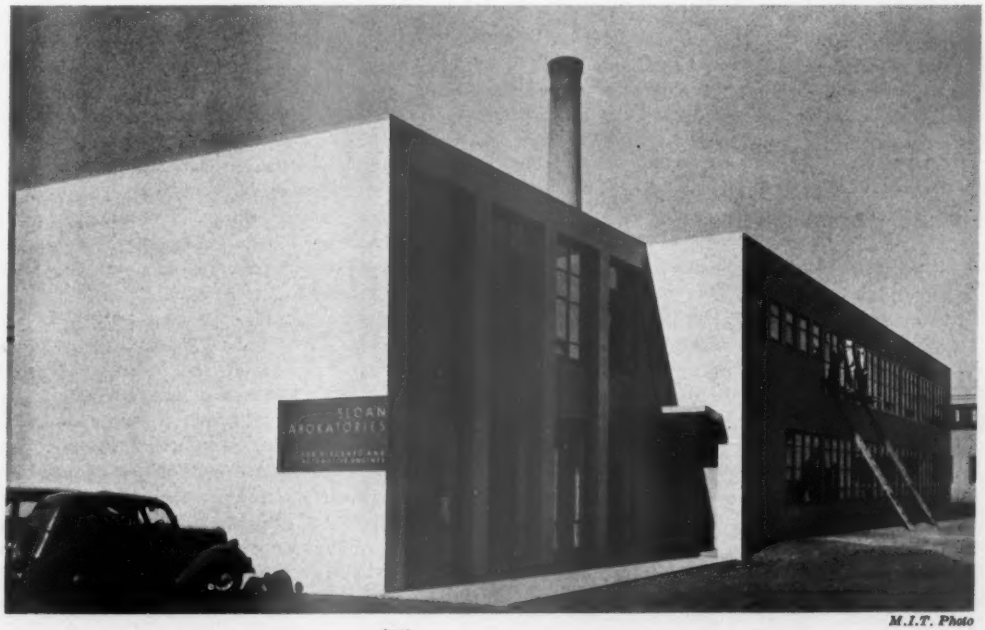
For Better Engines

Augmented Sloan Laboratory Permits Full Research Attack on Problems of Aviation and Automobile Motors

FULL utilization of the highly specialized and thoroughly equipped automotive testing floor which is the chief feature of the original Sloan Automotive Engine Laboratory erected over a decade ago, is insured for the future by completion of a two-story addition to the structure, which has been built through the generosity of Alfred P. Sloan, Jr., '95. The new building, which contains drafting, lecture, machine-shop, storage, and office space, and which enables the Institute again to display the rich possibilities of direct functional architecture, relieves the original laboratory of unfortunate congestion. This congestion could be tolerated well enough in ordinary times, but its elimination became imperative as Technology's abilities had to be more intensively drawn on in the mastery of problems of national defense.

Foresight which recognized early that the Institute's contributions in the design and testing of automotive and aeronautical internal-combustion engines would inevitably be of enhanced value to the country during the present unsettled state of world affairs prompted Mr. Sloan to make available $100,000 to meet the need specified by President Compton in his report to the Corporation in the fall of 1939. Available in June, 1940, the grant was put immediately to work, foundation caissons being got in place that month so that they were ready when contracts for general construction were let early in July. Active use of the building was begun last month by staff and students engaged in the study of automotive engineering.

The character of the activities for which the building was destined finds full recognition in the emphasis which the architects — Lawrence B. Anderson, '30, and Herbert L. Beckwith, '26 — have placed upon direct recognition of structural materials. Utility was a primary consideration in the plan of the building. Terra cotta and brick are exposed in the interior, being relieved by the use of a good deal of color, particularly in staff offices. The aesthetic possibilities of painted brick and naturally finished wood are considerable, and many areas in this structure secure full realization of them. Floors are of concrete save in the offices, where linoleum is used. Offices and lecture hall have been given acoustical treatment. Much furniture in all portions of the new building has been built in, including workbenches, cabinets, and book shelves and, of course, carefully systematized ranges of racks for the storage of technical equipment. Movable furniture is of gun-metal finish.



Finishing touches being applied to the new Sloan Laboratories Building. The exhibition room is on the ground floor, nearest the reader.

M.I.T. Photo

Built on caisson piles, with concrete beam and slab construction on grade, the addition has a steel frame and reinforced-concrete floors. Its foundation has been so designed that two additional stories can readily be added to the building. The original Sloan Building was constructed with caissons and grade beams calculated for the ultimate erection of an adjacent four-story building. The first floor of the new unit is devoted primarily to a machine shop and capacious storage room. Its principal feature from the public point of view is an exhibition area opening off the entrance hall and connected to the original laboratory. The exhibition space will be occupied by automotive and airplane engine displays of particular interest. It will be used for exhibitions pointing out the currently significant as well as the historically important. Above the exhibition space, on the second floor, is a commodious classroom, the remainder of this floor being given over to a large drafting room and to offices for the staff.

M.I.T. Photo

The slate plaque emphatic on the façade of the laboratories is one of the distinctions of design marking the building.

Both the drafting room and the first-floor machine shop are lighted by fluorescent tube fixtures, some light from which in the drafting room is diffused from the ceiling. The drafting room also receives daylight through a range of windows high above the floor. Fenestration throughout the building has been planned to secure the best lighting possible and to provide optimum conditions of ventilation, with a system of staggered vents in the windows affording well-spaced ceiling ventilation and concentrated ventilation at sill height. The main distribution duct of the ventilating system which runs through the drafting room has been tapped to supply air under forced circulation to the offices, so that a sufficient pressure differential between interior and exterior may be maintained to hold blown-in dust to a minimum. Mullions between windows have been designed so as to accommodate interior partitions if additional ones should be desired in future.

The vent sections of the many-windowed east wall in this staggered arrangement afford interesting patterning when they are viewed from the exterior. The east wall, with the strong vertical lines of supporting columns between bays and of mullions within the bays as well as with symmetrical configuration of vents, thus possesses considerable liveliness, which balances effectively the vigorous simplicity of the unbroken brick wall constituting the southerly face of the addition. The south wall is relieved only by a sharply contrasting black slate plaque bearing the name of the building. This wall is unbroken because it constitutes the platform end of the second-story lecture room and provides continuous wall for display in the ground-floor exhibition area.

The original Sloan Building was erected in 1929 with funds provided by Mr. Sloan and was equipped largely through the generosity of Henry M. Crane, '95. It was designed purely as a testing space, but auxiliary services, such as computing rooms and storage and machine-shop facilities, took up part of the test floor. Staff offices were at some distance from the testing floor, as were lectures and classes in design. As time went on, considerable congestion resulted from the lack of storage space in the building itself, and hence a not inconsiderable portion of the very adequate and specialized testing floor was pre-empted for nonspecialized purposes. The present addition makes possible employment of the testing floor to the fullest advantage and in addition will facilitate both teaching and research through the consolidation of auxiliary services and the gathering of staff and students close to the principal focus of their research and experimental activities.

Option 2 — automotive engineering — of the Institute's Course in Mechanical Engineering, will have its headquarters in the Sloan Laboratories, which will also be the center of much research on aircraft engines in connection with governmental defense programs. Through manufacturers and through the National Advisory Committee for Aeronautics, many investigations of this sort are already going on. In charge of the laboratories is C. Fayette Taylor, '29, Professor of Automotive Engineering. Research is supervised by Edward S. Taylor, '24, Associate Professor of Automotive Engineering. Dean A. Fales, '14, Associate Professor of Automotive Engineering, is concerned with the automotive vehicle as a whole, rather than primarily with its power plant. Augustus R. Rogowski, '28, Assistant Professor of Aeronautical Engineering, is responsible for work in the laboratory.

Alterations

ON recommendation of the Visiting Committee of the Department of Aeronautical Engineering, extensive alterations have been made in the Guggenheim Aeronautical Laboratory to permit the training of an increased number of engineers in this field. The large wooden wind tunnel, now obsolete, was dismantled and a second floor installed in the two-story space thus released. These alterations have added 1,700 square feet of new drafting-room space and two large lecture rooms, and have permitted enlargement of the aeronautical laboratory. There are also a new instrument laboratory double the size of the former one, a graduate-student room, special research rooms, and an airplane structures laboratory within which is space for a new and more compact wind tunnel to replace the obsolete structure. With the relief provided by the new addition to the Sloan Laboratory, which frees the entire fourth floor of the Guggenheim Building for meteorological studies, the Institute is now equipped to care for a 30 per cent increase in registrants in Aeronautical Engineering.

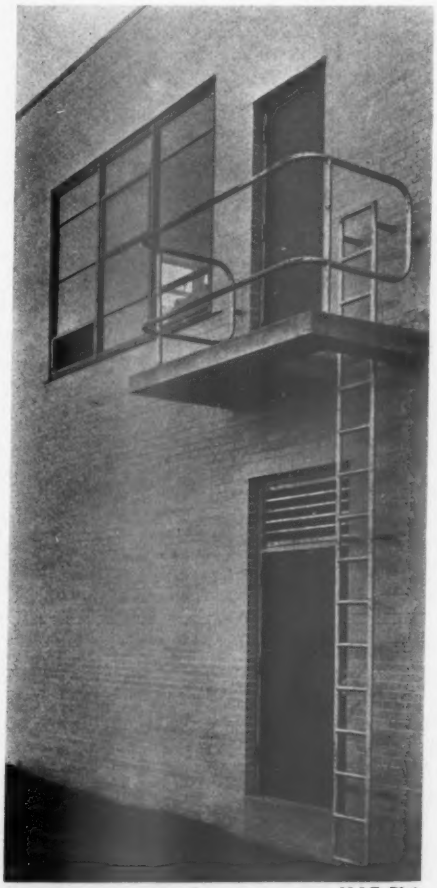
Nuclear Physics

PROGRESS in one of the most active and promising fields of modern science, nuclear physics, was the subject of a special conference held at the Institute from October 28 to November 2, when more than 600 distinguished experimenters, including three winners of the Nobel Prize, participated in the sessions. The meeting was sponsored by the American Institute of Physics in co-operation with Technology.

Nuclear physics is the investigation of the physical phenomena which occur within the nucleus of the atom, the ultimate building block of which all matter is composed. Scientists have discovered that some of these phenomena can be harnessed for man's use. To the divers practical applications of this branch of science the conference devoted most of its attention. These applications range over a wide field — biology, chemistry, radiology, metallurgy, geology, and public health, to name but a few — and the conference discussed the important problems and trends in all of them.

In chemistry, for example, the techniques of nuclear physics have enabled scientists to follow and study by the so-called tracer method complex reactions they could not otherwise investigate. This tracer technique, by which components of the reactions are made artificially radioactive so that they can be easily detected, has also proved invaluable to biologists studying intricate life processes: Radioactive iodine has helped the study of thyroid diseases immeasurably; radioactive iron has given clues to anemia; radioactive sulphur has shed light on how the body uses vitamin B_1. Many of these studies obviously hold significant implications for medicine. Nuclear physics has also made its contributions to metallurgy, and its uses in geology, especially in helping to determine the age of the earth, are well known. Possibly the most dramatic applications have been in the field of radiology, where nuclear physics has constituted one of science's most effective weapons against cancer.

Robley D. Evans, Associate Professor of Physics at Technology and chairman of the committee in charge of the conference, said that "the rapidly increasing number of applications of methods and apparatus characteristic of nuclear physics emphasized the usefulness of a joint conference between physicists and their colleagues in other fields of science. The purposes of the conference were to bring together investigators who were widely separated geographically, to provide a forum for the assembling and correlation of present knowledge and problems, and to direct attention toward fundamental lines of research which should be the subject of future investigations."



M.I.T. Photo

A fire escape can be efficient and at the same time interesting; this one is at the rear of the new Sloan Building.

A feature of the conference was a dinner at which Dr. Compton introduced Professor Enrico Fermi of Columbia University, holder of the Nobel Prize for 1938, who spoke on nuclear fissions.

Among the distinguished scientists who were chairmen of the various technical sessions were James B. Conant, President, Harvard University; Lyman J. Briggs, National Bureau of Standards; Frederick Seitz, Jr., University of Pennsylvania; Samuel C. Lind, '02, University of Minnesota; Charles S. Barrett, Carnegie Institute of Technology; Alfred C. Lane, Tufts College; Hugh S. Taylor, Princeton University; Dr. George W. Holmes, Massachusetts General Hospital; Dr. James H. Means, '06, Massachusetts General Hospital and Harvard University; Leason H. Adams, Carnegie Institution of Washington; Harold C. Urey, Columbia University; Dr. George E. Pfahler, University of Pennsylvania; Dr. Joseph C. Aub, Huntington Memorial Hospital and Harvard University; Kenneth T. Bainbridge, '25, Harvard University; G. Failla, Memorial Hospital, New York City; Dr. Rollin H. Stevens, Detroit, Mich.; Joseph G. Hamilton, University of California; Edith H. Quimby, Memorial Hospital, New York City; Dr. Stafford L. Warren, University of Rochester School of Medicine and Dentistry; Charles Packard, Columbia University; Detlev W. Bronk, Cornell University Medical College; David R. Goddard, University of Rochester; and Robert J. Van de Graaff, M.I.T.

Assisting Professor Evans on the committee in charge were Elmer Hutchisson, '24, University of Pittsburgh, Secretary; Henry A. Barton, director, American Institute of Physics; Edw. U. Condon, Westinghouse Electric and Manufacturing Company; Lee A. DuBridge, University of Rochester; Dr. Failla; Clark Goodman, '40, M.I.T.; Ernest O. Lawrence, the distinguished physicist of the University of California, awarded the Nobel Prize in 1939 for the cyclotron; and Dr. Urey, whose discovery of heavy water won the 1934 Nobel Prize.

Memorabilia

AN exhibition of Emma Savage Rogers' memorabilia was opened last month in the room at the Institute named for her and

dedicated to the use of Technology women. As the wife of William Barton Rogers, the Institute's first President, Mrs. Rogers shared with him the tribulations and the triumphs of the Institute's early years, and until her death in 1911 her interest in its progress never waned.

The exhibition includes photographs, letters, and several of Mrs. Rogers' gowns. Also on view is a silver tray which was presented to her by the students in the classes from 1865 to 1885 and which, after her death, was given to the Institute by her nieces for use by the wives of Presidents of Technology. The collection also contains copies of books she edited, including the life and letters of her husband, as well as the letters of her father, which she so ably edited at the age of eighty-two. Among the photographs of Mrs. Rogers is a miniature on ivory made when she was about eighteen years old.

The collection was arranged by the exhibits committee of the Emma Rogers Room, which is composed of Mrs. Frederick K. Morris, chairman, Mrs. Walter C. Voss, and Miss Florence W. Stiles, '22.

M.I.T. Photo

Commodious but compact, a locker room adjoining the showers in the new Alumni Pool Building

The Council Resumes

HIGH mark in attendance — 125 members and guests being present — was set at the first meeting of the Alumni Council for this academic year, in Pritchett Hall on the last Monday in October. This was the 215th meeting of the Council. Henry E. Worcester, '97, President of the Alumni Association, was in the chair. After introductions and committee reports, including that of Francis A. Barrett, '24, chairman of the 1940 Alumni Day, whose good work was again commended, Mr. Worcester proceeded to the presentation of President Compton as the first of a group of speakers on aspects of the national defense program.

Talking as a member of the National Defense Research Committee, Dr. Compton sketched the Institute's participation in defense preparations, including the loan of staff members to the government, the conduct of special research at the Institute itself, and the offering of intensive training courses to prepare men for particular functions in defense. Professor George R. Harrison, Director of Applied Physics and of the Research Laboratory of Experimental Physics, who is chairman of the instrument section of the National Defense Research Committee, next described the work being done by his group, recounting various interesting aspects of the canvassing of ideas in connection with defense.

F. Leroy Foster, '25, assistant to the Director of the Division of Industrial Cooperation, then discussed calls for men as the defense program occasions them. Specialized experience has been particularly sought thus far, but as time goes on the specifications are expected to be materially broadened. At least 16,000 trained engineers, according to conservative estimates, will be needed by industry within the next year. Some personnel men of large organizations set the figure far higher. In helping to meet this demand, the Placement Bureau of the Institute is finding the information blanks returned by Alumni about a year ago very useful, Dr. Foster said.

Professor Jerome C. Hunsaker, '12, Head of the Departments of Mechanical Engineering and Aeronautical Engineering, spoke as a member of the National Advisory Committee for Aeronautics, explaining that in aircraft production the chief problem is one of procurement rather than of research, but that research is being continued very thoroughly.

Visiting Committee Report

THE Committee on Museum * met at the Institute for the purpose of making a preliminary survey of the museum layout and exhibits, and of discussing the entire museum situation. A second meeting was devoted

* Members of this Committee for 1939–1940 were William S. Newell, '99, Chairman, Franklin W. Hobbs, '89, Willis R. Whitney, '90, Charles G. Abbot, '94, Robert P. Shaw, '23, Henry B. Allen, and Henry P. Kendall.

to an interesting and fairly thorough discussion of the aims and activities of the Museum and to a tour of inspection of the exhibits.

The Dard Hunter Paper Museum is not only most interesting but of much educational value to the Institute, and the Committee have no suggestions regarding it. The Nautical Museum appears to need more space for its present exhibits as well as for additional ones that probably will be given to the Institute in the near future. This museum could use the adjacent lecture room. The Hobby Shop is a very valuable adjunct to the regular work of the Institute. It needs more space and some additional tool equipment.

The present method of housing exhibits by glass-covered insets in the corridor walls appears to be not only most practical but the best way to handle the situation at the Institute, as technical or scientific exhibits bearing upon the work of any particular Department can thus be placed along the corridors passing through the Department. This policy should be continued.

The Institute appears to have no set plan for the future expansion of its museum work. This Committee believe that a definite method of selecting and procuring exhibits, and of refusing exhibits that may be offered but are not suitable or of any particular value to the work of the Institute, should be established.

The following questions are suggested as basis for the establishment of such a general policy: Should exhibits be installed for use by students individually or by students with their instructors or by both methods? In addition to carrying out the primary idea of value to the student, should the objective of the museum work be to attract the public, tell the story of the Institute and develop interest in it, or a combination of all of these?

The museum project should be considered as a long-time development — a policy which would have a bearing upon the immediate selection or acceptance of exhibits. With a carefully established plan, each year some exhibits — a few only — can be added which will harmonize with the work of preceding years and that of the years to come. The Committee feel that the historical end should be relatively small, perhaps just touching the high spots of various scientific and industrial developments, and that expansion of exhibits to cover modern developments should be of major concern.

The Committee are indebted to Professor James R. Jack and Arthur C. Watson, Chairman of the Technology Museum, for the time, information, and enthusiastic assistance they have rendered to the Committee.

M.I.T.—A Mexican View

OBSERVATION convinces us that the more the economic potentiality of a country increases, the greater the influence and the scientific support of its universities becomes," says M. Pacheco Moreno, discussing the M.I.T. in a special article in the newspaper

M.I.T. Photo

The Class of 1923 garden in front of the Alumni Pool, as it awaits next spring's burgeoning

El Universal of Mexico City. "This phenomenon," Sr. Moreno holds, "is due to the fact that the industry of a nation, in order to live and develop, must of necessity find in its institutions of higher learning its strongest support; if it fails to do so, the country runs the risk of being invaded by foreign technicians who, even though they come in the name of collaboration, will jealously guard and never reveal to the nationals the secrets of their specialty, leaving local industry from a certain point of view the slave of foreign control and subject to all its eventualities.

"As an objective proof of this statement we are going to discuss the case of the Massachusetts Institute of Technology because it has seemed to us the nearest to our own experience, also because a distinguished Mexican, the engineer Manuel Sandoval Vallarta ['21] has won a prominent place on the staff there — a fact that we consider the best reply to those who do not know nor understand us — and finally because the knowledge of university life in other countries will serve as a mainspring, an example and stimulus to our own."

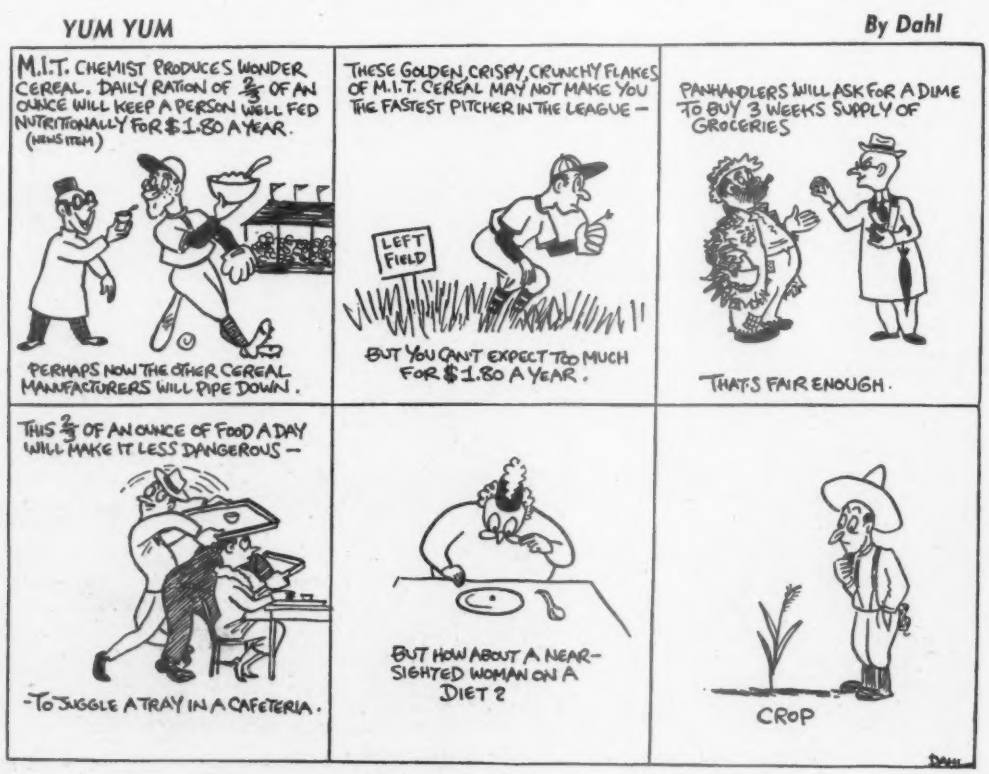
After sketching the origin, history, and present status of the Institute, Sr. Moreno points out: "An institution which in its beginnings was essentially technical, very soon had to establish studies of a purely speculative nature, a necessity which was imposed upon it not only by the increasing industrial progress of the United States and of the world but because nobody now can deny that science must be, and will be, turned to practical uses, and the more so the more disinterestedly it is cultivated; and that if it is neglected, anemia results in the culture of a country and in its technical skill.

"The Institute does not live cut off from the world; all vital forces around it converge to effect its constant advance: The state gives it money and encouragement, realizing that it is training the men the American nation needs, but leaves it absolute liberty in the choice and planning of its activities. The graduates retain their connection with it by bonds of culture and comradeship with an interest which at times manifests itself in material contributions, as, for example, in 1917, when they built the magnificent Walker Building at a cost of many thousands of dollars. Many persons have left it large bequests, even entire estates, some for its support, others for the creation of scholarships for distinguished students or for those who wish to go to other countries for purposes of research. American industrialists appreciate and realize so fully the value of the work accomplished by the Institute that they are continually contributing fabulous sums of money. . . .

"In this way the Institute lives as the best example of co-operation and of liberty, proving that science is not static and petrified but a treasure in a state of evolution, which lends to industrial and manufacturing technique its best support and demands of the student that he investigate, work, and contribute with his truth to the welfare of humanity."

New Food

A FOOD supplying an optimum of all nutritive requirements of the normal person has been developed in the Department of Biology and Public Health by Professor Robert S. Harris, '28, (*Concluded on page 91*)


YUM YUM
By Dahl
M.I.T. CHEMIST PRODUCES WONDER CEREAL. DAILY RATION OF 2/3 OF AN OUNCE WILL KEEP A PERSON WELL FED NUTRITIONALLY FOR $1.80 A YEAR. (NEWS ITEM)
PERHAPS NOW THE OTHER CEREAL MANUFACTURERS WILL PIPE DOWN.
THESE GOLDEN, CRISPY, CRUNCHY FLAKES OF M.I.T. CEREAL MAY NOT MAKE YOU THE FASTEST PITCHER IN THE LEAGUE —
LEFT FIELD
BUT YOU CAN'T EXPECT TOO MUCH FOR $1.80 A YEAR.
PANHANDLERS WILL ASK FOR A DIME TO BUY 3 WEEKS SUPPLY OF GROCERIES
THAT'S FAIR ENOUGH.
THIS 2/3 OF AN OUNCE OF FOOD A DAY WILL MAKE IT LESS DANGEROUS —
-TO JUGGLE A TRAY IN A CAFETERIA.
BUT HOW ABOUT A NEAR-SIGHTED WOMAN ON A DIET?
CROP
DAHL

Francis Dahl depicts thus in the Boston Herald *possibilities suggested to his mind by a new food formula.*

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NORTON ABRASIVES

Industry Uses Grinding Wheels in Great Variety

Norton Grinding Wheels are made in one hundred thousand combinations. Factory and warehouses stock approximately two and a half million Norton Wheels to meet the immediate needs of industry.

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BEHR-MANNING DIVISION, TROY, N. Y. (ABRASIVE PAPER AND CLOTH)

LINGUISTICS AS AN EXACT SCIENCE

(*Continued from page 63*)

According to the third term, which consists of two columns, the word can begin with any consonant of the first column followed by *r*, or with *g*, *k*, *f*, or *b* followed by *l*. The *s* with a wedge over it means *sh*. Thus we have "shred," but not "shled." The formula represents the fact that "shled" is un-English, that it will suggest a Chinese's pronunciation of "shred" or a German's of "sled" (*sl* is permitted by term 7). The Greek theta means *th;* so we have "thread" but not "thled," which latter suggests either a Chinese saying "thread" or a child lisping "sled." But why aren't *tr*, *pr*, and *pl* in this third term? Because they can be preceded by *s* and so belong in term 6. The fourth term similarly means that the word can begin with a consonant of the first column followed by *w*. *Hw* does not occur in all dialects of English; in ordinary spelling it is written backwards, *wh*. If the dialect does not have *hw*, it pronounces the spelled *wh* simply as *w*. *Thw* occurs in a few words, like "thwack" and "thwart," and *gw*, oddly enough, only in proper names, like Gwen or Gwynn. *Kw*, ordinarily spelled *qu*, can have *s* before it and therefore belongs in term 6.

The fifth term indicates that the word may begin with one of the first-column consonants followed by *y*, but only when the vowel of the word is *u;* thus we have words like "hue" (*hyuw*), "cue," "few," "muse." Some dialects have also *tyu*, *dyu*, and *nyu* (e.g., in "tune," "due," and "new"), but I have set up the formula for the typical dialects of the northern United States, which have simple *tu*, *du*, *nu* in these words. The sixth term indicates pairs that can commence a word either alone or preceded by *s*, that is, *k*, *t*, or *p* followed by *r*, also *kw* and *pl* (think of "train," "strain"; "crew," "screw"; "quash," "squash"; "play," "splay"). The seventh term, which means the word can begin with *s* followed by any one of the consonants of the second column, completes the parts of the word that can precede its vowel.

The terms beyond the eighth show what comes after the vowel. This portion is rather more complex than the beginning of the word, and it would take too long to explain everything in detail. The general principles of the symbolism will be clear from the preceding explanations. The ninth term, with its zero, denotes that a vowel can end the word if the vowel is *a* — which means (1) the vowel of the article "a" and the exclamation "huh?" and (2) the vowel of "pa," "ma," and the exclamations "ah!" and "bah!" — or the vowel can end the word if it is the *aw* sound, as in "paw," "thaw." In some dialects (eastern New England, southern United States, South British) the vowel ending occurs in words which are *spelled* with *ar*, like "car," "star" (*ka*, *sta*, in these dialects), but in most of the United States dialects and in those of Ireland and Scotland these words end in an actual *r*. In eastern New England and South British dialects, but not in southern United States, these words cause a linking *r* to appear before a vowel beginning a following word. Thus for "far off" your Southerner says *fa of;* your Bostonian and your Britisher say *fa rof*, with a liquid initial *r;* but most of the United States says *far of*, with a rolled-back *r*. For some dialects, term 9 would be different, showing another possible final vowel, namely, the peculiar sound which the Middle Westerner may notice in the Bostonian's pronunciation of "fur," "cur" (*fə*, *kə*) and no doubt may find very queer. This funny sound is common in Welsh, Gaelic, Turkish, Ute, and Hopi, but I am sure Boston did not get it from any of these sources.

Can one-syllable words end in *e*, *i*, *o*, or *u*? No, not in English. The words so spelled end in a consonant sound, *y* or *w*. Thus, "I," when expressed in formula pattern, is *ay*, "we" is *wiy*, "you" is *yuw*, "how" is *haw*, and so on. A comparison of the Spanish *no* with the English "No!" shows that whereas the Spanish word actually ends with its *o* sound trailing in the air, the English equivalent closes upon a *w* sound. The patterns to which we are habituated compel us to close upon a consonant after most vowels. Hence when we learn Spanish, instead of saying *como no*, we are apt to say *kowmow now;* instead of *si*, we say our own word "see" (*siy*). In French, instead of *si beau*, we are apt to say "see bow."

Term 10 means that *r*, *w*, or *y* may be interpolated at this point except when the interpolation would result in joining *w* and *y* with each other. Term 11 means that the word may end in any single English consonant except *h;* this exception is most unlike some languages, e.g., Sanskrit, Arabic, Navaho, and Maya, in which many words end in *h*. The reader can figure out terms 12, 13, and 14 if he has stuck so far. A small *c* means *ch* as in "child"; *j* is as in "joy." Term 13, which contains these letters, expresses the possibility of words like "gulch," "bulge," "lunch," and "lounge." Term 14 represents the pattern of words like "health," "width," "eighth" (*eytθ*), "sixth," "xth" (*eksθ*). Although we can say "nth" power or "fth" power, it takes effort to say the unpermitted "sth" power or "hth" power. "Hth" would be symbolized **eycθ*, the star meaning that the form does not occur. Term 14, however, allows both *mθ* and *mpf*, the latter in words like "humph" or the recent "oomph" (*umpf*). The elements of term 15 may be added after anything — the *t* and *s* forms after voiceless sounds, the *d* and *z* after voiced sounds. Thus, "towns" is *tawnz*, with *wnz* attained by term 10 plus 11 plus 15; whereas "bounce" is *bawns*, with *wns* by 10 plus 12. Some of the combinations resulting in this way are common; others are very rare but still are possible English forms. If Charlie McCarthy should pipe up in his coy way, "Thou oomphst, dost thou not?"; or a Shakespearean actor should thunder out, "Thou triumphst!" the reason would be that the formula yields that weird sputter *mpfst* by term 14 plus term 15. Neither Mr. Bergen nor Mr. Shakespeare has any power to vary the formula.

The overriding factor applicable to the whole expression is a prohibition of doubling. Notwithstanding whatever the formula says, the same two consonants cannot be juxtaposed. While by term 15 we can add *t* to "flip" and get "flipt" ("flipped"), we can't add *t* to "hit" and get "hitt." Instead, at the point in the patterns where "hitt" might be expected, we find simply "hit" (I hit it yesterday, I flipt it yesterday). Some languages, such as Arabic, have words like "hitt," "fadd," and so on, with both paired consonants distinct. The Creek Indian language permits three, e.g., *nnn*.

The way the patterns summarized in this formula control the forms of English words is really extraordinary. A new monosyllable turned out, say, by Walter Winchell or by a plugging adman concocting a name for a new breakfast mush, is struck from this mold as surely as if I pulled the lever and the stamp came down on his brain. Thus linguistics, like the physical sciences, confers the power of prediction. I can predict, within limits, what Winchell will or won't do. He may coin a word "thrub," but he will not coin a word "srub," for the formula cannot produce a *sr*. A different formula indicates that if Winchell invents any word beginning with *th*, like "thell" or "therg," the *th* will have the sound it has in "thin," not the sound it has in "this" or "there." Winchell will not invent a word beginning with this latter sound.

We can wheeze forth the harshest successions of consonants if they are only according to the patterns producing the formula. We easily say "thirds" and "sixths," though "sixths" has the very rough sequence of four consonants, *ksθs*. But the simpler "sisths" is against the patterns and so is harder to say. "Glimpst" (glimpsed) has *gl* by term 3, *i* by 8, *mpst* by 12 plus 15. But "dlinpfk" is eliminated on several counts: Term 3 allows for no *dl*, and by no possible combination of terms can one get *npfk*. Yet the linguist can say "dlinpfk" as easily as he can say "glimpsed." The formula allows for no final *mb*; so we do not say "lamb" as it is spelled, but as *lam*. "Land," quite parallel but allowed by the formula, trips off our tongues as spelled. It is not hard to see why the "explanation," still found in some serious textbooks, that a language does this or that "for the sake of euphony" is on a par with nature's reputed abhorrence of a vacuum.

The exactness of this formula, typical of hundreds of others, shows that while linguistic formulations are not those of mathematics, they are nevertheless precise. We might bear in mind that this formula, compared with the formulation of some of the English (or other) grammatical patterns that deal with meaning, would appear like a simple sum in addition compared with a page of calculus. It is usually more convenient to treat very complex patterns by successive paragraphs of precise sentences and simpler formulas so arranged that each additional paragraph presupposes the previous ones, than to try to embrace all in one very complex formula

Linguistics is also an experimental science. Its data result from long series of observations under controlled conditions, which, as they are systematically altered, call out definite, different responses. The experiments are directed by the theoretic body of knowledge, just as with physics or chemistry. They usually do not require mechanical apparatus. In place of apparatus, linguistics uses and develops *techniques*. Experimental need not mean quantitative. Measuring, weighing, and pointer-reading devices are seldom needed in linguistics, for quantity and number play little part in the realm of pattern, where there are no variables but, instead, abrupt alternations from one configuration to another. The mathematical sciences require exact measurement, but what linguistics requires is, rather, exact "patternment" — an exactness (*Continued on page 82*)

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LINGUISTICS AS AN EXACT SCIENCE

(*Continued from page 81*)

of relation irrespective of dimensions. Quantity, dimension, magnitude, are metaphors since they do not properly belong in this spaceless, relational world. I might use this simile: Exact measurement of lines and angles will be needed to draw exact squares or other regular polygons, but measurement, however precise, will not help us to draw an exact circle. Yet it is necessary only to discover the principle of the compass to reach by a leap the ability to draw perfect circles. Similarly, linguistics has developed techniques which, like compasses, enable it without any true measurement at all to specify *exactly* the patterns with which it is concerned. Or I might perhaps liken the case to the state of affairs within the atom, where also entities appear to alternate from configuration to configuration rather than to move in terms of measurable positions. As alternants, quantum phenomena must be treated by a method of analysis that substitutes a point in a pattern under a set of conditions for a point in a pattern under another set of conditions — a method similar to that used in analysis of linguistic phenomena.

Physics and chemistry, dealing with inanimate matter, require chiefly inanimate apparatus and substances for their experiments. As conducted today upon a large scale, they require highly wrought physical equipment at every step, immense investments in physical plant. Their experiments are costly to conduct, both absolutely and relatively to the number of scientists. Experimental biology uses much inanimate apparatus, too, but its fundamental apparatus is its experimental animals and plants and their food, housing, and growth facilities. These also are expensive in the quantities needed. No one grudges the expense, either here or in the physical sciences, so long as an increase in human knowledge and welfare is promised.

The apparatus of linguistics is much less expensive than that of these sciences, but it, too, costs money. The experimental linguist, like the biologist, uses and must have experimental animals. Only, his "animals" are human. They are his informants and must be paid for working with him. Sometimes he must make trips to Indian reservations or African villages where his informants live; at other times it is more economical to transport them to him. They provide the field for experimental investigation. They are apparatus, not teachers. It is as important to study in this way languages of Indians, Africans, and other aborigines as it is to study the English dialects of Brooklyn, Boston, Richmond, or London.

While informants are the basic apparatus, the linguist can improve and speed up his work with the aid of mechanical tools, just as the biologist studies his animals and plants with the aid of microscopes, x-ray machines, and other costly instruments. The linguist is aided by judicious use of good phonographic reproducing devices. Much could also be done with the help of business machines.

Although linguistics is a very old science, its modern experimental phase, which stresses the analysis of unwritten speech, could be called one of the newest. So far

as our knowledge goes, the science of linguistics was founded, or put on its present basis, by one Panini in India several centuries before Christ. Its earliest form anticipated its most recent one. Panini was highly algebraic, i.e., pattern symbolic, in his treatment; he used formulas in a very modern way for expressing the obligatory patterns of Sanskrit. It was the Greeks who debased the science. They showed how infinitely inferior they were to the Hindus as scientific thinkers, and the effect of their muddling lasted two thousand years. Modern scientific linguistics dates from the rediscovery of Panini by the Western world in the early Nineteenth Century.

Yet linguistics is still in its infancy so far as concerns wherewithal for its needed equipment, its supply of informants, and the minimum of tools, books, and the like. Money for mechanical aids, such as I referred to above, is at present only a happy dream. Perhaps this condition results from lack of the publicity the other sciences receive and, after all, fairly earn. We all know now that the forces studied by physics, chemistry, and biology are powerful and important. People generally do not yet know that the forces studied by linguistics are powerful and important, that its principles control every sort of agreement and understanding among human beings, and that sooner or later it will have to sit as judge while the other sciences bring their results to its court to inquire into what they mean. When this time comes, there will be great and well-equipped laboratories of linguistics as there are of other exact sciences.

FLYING UP

(*Continued from page 65*)

ground without any forward run and could keep it in the air indefinitely with satisfactory control. It was able to fly backward, sideways, or forward, could make turns at any desired radius, and could be turned completely about in the air while remaining directly over one spot. Enough thus has been done to prove that controlled vertical flight is possible.

Other experimenters have been working along similar lines but with indifferent success. Toward the end of the World War two Austro-Hungarians, Lieutenant Stefan Petroczy and Professor Theodore von Kármán, developed a machine to replace kite balloons as a means of observation. They actually built a helicopter which had a gross weight of about 3,200 pounds and was powered with three 120-horsepower rotary engines. It carried one observer and a machine gun in a tanklike enclosure on top, and enough fuel for a flight of one hour. It was never allowed to fly freely, but was attached to stabilizing ropes. After fifteen successful flights, it was finally damaged badly in a landing and was abandoned. Although the machine had demonstrated a certain degree of value from the military angle, it lacked any means of propelling itself from point to point in the air.

The world was still taking large grains of salt with reports that a couple of bicycle mechanics named Wright had a flying machine that really flew, when another inventor in America began jotting down notes and making sketches on the backs of old (*Continued on page 84*)

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FLYING UP

(*Continued from page 83*)

envelopes. Emile Berliner of Washington was no novice at invention. The gramophone and a number of other devices now commonplace had been born of like scraps of paper carried about in the Berliner coat pockets. As early as 1902 he had built and tested a five-cylinder rotary gasoline engine. Not unnaturally, then, this flying business caught his fancy. But he thought that the boys in Dayton were off on the wrong foot. The way to fly was straight up; the proper machine was the helicopter.

He tried it — persistently. For a while he collaborated with J. Newton Williams, who had been experimenting with helicopters for some years. Williams had worked with Glenn Curtiss at Hammondsport, N. Y. Berliner and Williams built a machine together in 1909, after having tested the lifting power of their airscrews during 1908. An accident put an end to the Berliner-Williams machine but did not quench Emile's enthusiasm. No work was done, however, between 1909 and 1919. At the latter date Henry, Emile's son, having learned to fly while in the United States Army Air Corps, took over active work, and his father backed him financially. Henry did succeed in building a machine (his second, now in the Smithsonian Institution) which was probably the first helicopter to achieve dirigibility. Stability and other problems proved more difficult. By 1923, however, having built and test-flown three other full-size machines, the Berliners gave up "helicopting" as a bad job, and turned their attention to other activities.

About the same time, a Russian engineer, De Bothezat, persuaded the United States Army Air Corps to build at McCook Field, Dayton, Ohio, a huge and awkward-looking machine with four six-bladed lifting airscrews driven by a 220-horsepower engine. This machine weighed 3,600 pounds complete, and when tested by the technical section at Dayton in mid-December of 1922 it rose to an altitude of about six feet and stayed in the air for not quite two minutes. It did, however, exhibit considerably greater stability in flight than Berliner machines. The results obtained at that time were not striking enough to warrant continuing the project, and the Air Corps lost interest. According to report, De Bothezat was designing another machine for a military competition when he died early this year.

Certain European governments were not so easily discouraged about helicopters. Etienne Œmichen of the Peugot Company of France experimented continuously after the close of the War in 1918 and built several machines, one of which depended for part of its lift and much of its stability on an attached gas-filled balloon. The most successful (which, however, was minus any balloon) set a record in 1924 by flying a closed kilometer circuit, with an all-up weight of 4,400 pounds and 120-horsepower engine. This machine made a total of over a thousand flights, but never got more than a few feet off the ground. Another Frenchman, Louis Breguet, who built a famous line of bombing planes during 1917 and 1918, experimented with helicopters long before the War, beginning in 1907. He continued work on direct-lifting machines and made a number of different

types culminating in a machine which was demonstrated during the post-War period. His most successful machine made a number of closed-circuit flights at low altitudes, but its stability left much to be desired.

In America, the Curtiss Aeroplane and Motor Corporation became interested in the idea of one of its own engineers, Maitland B. Bleecker. Bleecker's helicopter had four winglike blades, each with its own stabilizing surfaces, rotating about the vertical axis of the machine. Each of these four airplanelike elements was driven by its own propeller, gear-connected to an air-cooled radial engine. It made several "flights" inside the hangar at Valley Stream Airport where it was built. With the onset of the depression of 1930, however, and in view of difficulties that were cropping up both in the ability to cool the engine and in matters of stability, the Curtiss Corporation saw fit to drop the whole project without carrying out any very conclusive tests.

For almost ten years little was heard of the helicopter in America. Engineers were kept busy with the rapid development of the airplane and seemed to have little energy left for problems of vertical flight. In Germany, however, designers had been quietly at work. Without advance notice it was suddenly announced, in 1937, that the Focke-Achgelis Company had built a successful helicopter, one that conformed to all the desirable specifications for such machines. It was reported able to rise and to ascend vertically, to hover, to move ahead, astern, or sideways at the will of the pilot. Some understandable skepticism existed in this country over the first reports, but they were dispelled by repeated demonstration. Stimulated by the reported success of the German helicopter, toward the end of the 1930's, several small groups of engineers in the United States began independent simultaneous studies. In 1938, Representative Dorsey of Pennsylvania introduced a bill in Congress to appropriate $2,000,000 for the development of rotary-wing aircraft for all government agencies. Of this amount, the Army was authorized to expend $300,000 for research on autogiros or helicopters.

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BORING HISTORY

(*Continued from page 67*)

cently, it was the best drilling instrument for small holes, such as the firing vent of cannon. Such a drill had a flat steel bow, but cruder forms were bow shaped only, as shown in Fig. 9.

The pump drill (Fig. 10) is an efficient device for drilling holes less than an eighth of an inch in diameter. It has been invented independently by various races, including our American Indians. The monk Theophilus, who wrote a treatise on various tools and methods about 1100, says: "Pearls . . . are perforated with a fine steel tool fixt in wood. It has a small wheel and there is another piece of wood in which it (the drill) turns, to which the cord is attached to make it turn." No bow is mentioned. The "wheel" is evidently the flywheel, and the "piece of wood," the crossbar in which the shaft turns and to which the driving cord is attached. It is called a pump drill on account of the pumping, or up-and-down, motion of the crosspiece. It can be rotated at a higher speed than the common geared hand drill, and for holes less than one-sixteenth of an inch in wood and in iron it is very efficient. It has a positive and not a friction drive, and the downward thrust of the arm supplies not only the speed but the pressure.

Any of these drill-driving devices can be applied to either flint-tipped drillshafts or to grinding methods for hard stones. Regardless of the driving devices, or whether the shaft was rolled between the palms, beads and other ornaments have been pierced by lapping out the hole. Precious stones are pierced today by this method. The dies through which the smaller sizes of wire are drawn are made of diamonds and sapphires because they hold their size well. To pierce these small holes, an iron wire is rolled in diamond dust and rotated at a very high speed in contact with the stone to be drilled. Prehistoric and primitive men have accomplished the same results with less apparatus, at a greater cost of time and labor.

Holes produced by these methods are relatively small — not over two inches in diameter — but earlier mention has been made of larger holes drilled in solid rock. For examples of these we must go to Egypt. There is no doubt of the existence of these holes, some of which are over four inches, nor does there seem to be any doubt that similar holes were drilled (*Concluded on page 88*)

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BORING HISTORY

(*Concluded from page 86*)

with core drills, as the cores have been found. Flinders Petrie, the famous English archaeologist and Egyptologist, mentions several examples of such drilling. For instance, he refers to a 4½-inch hole drilled in diorite, showing the marks of a single cutting point which made seventeen complete revolutions. A piece of diorite "waste" — a core? — of about the same size was also found. He further says that the drill used in hollowing out the granite coffin in the great pyramid was 4.2 inches in diameter and states: ". . . All over the platform [at El Bersheh], the surface is apparently covered with the circular grooves of large tubular drills about 18 inches diameter." * Petrie held that the Egyptians used core, or tubular, drills set with precious stones, but not all his fellow members agreed on this particular detail. They did not dispute his contention that the holes were drilled with tubular drills, but they did not accept Petrie's reconstruction of the methods by which the drilling was accomplished. Possibly Petrie was convinced that some of the criticisms were just, as he has not — so far as I know — referred to the subject again. There seems to be no doubt that the holes, or some of them, were drilled with core drills, but how these drills were constructed or driven is still an open question.

* *Journal of the Anthropological Institute of Great Britain and Ireland*, XIII, 94.

NET RETURNS FROM THE BANKS

(*Continued from page 72*)

from an average of three hundred thousand to one of about thirty thousand. Chief quick-freezing methods are: first, direct freezing by immersion in a sodium chloride brine; second, indirect immersion or spraying with calcium chloride brine; third, the single plate system, whereby the article to be frozen is placed on a metal plate, the under side of which is in contact with calcium chloride brine; fourth, freezing between two metal surfaces under pressure. The latter method involves placing the fish fillets on a flexible belt which is run into the freezing tunnel. An upper belt presses against the fillet, and the two belts travel through the freezing zone, where calcium chloride brine is sprayed on the under surface of the lower belt and on the upper surface of the upper belt. Out of this method was developed the multiplate froster — a series of refrigerated, aluminum-alloy plates with passages through which the refrigerant is circulated. The plates are enclosed in an insulated cabinet which has sliding doors for quick loading and unloading. With the plates at 25 degrees Fahrenheit, unpackaged fish fillets and steaks freeze in from five to ten minutes.

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MAIL RETURNS

(*Concluded from page 50*)

carry the same sense if written: "The more complex and strange the subject, the more difficult and important it is to write about it simply and clearly"?

Or: "Such instinctive conclusions, which teach the reader nothing, are a consequence partly of the socially beneficial industrial utilization of the results of research and partly of that egocentricity which is the less attractive aspect of American individualism."

Or: "The philosophical import of scientific discovery, whether that be in a further expansion of an expanding universe or in a further reduction of ultramicroscopic infinitesimality, works powerfully upon the mystical."

Or: "A piece of popularization so constructed is far superior in social value to writing which seeks through what Professor Frederick G. Keyes calls 'imagination shock' to jolt the reader by means of a concatenation of superlatives and strings of astronomical figures."

If this article is not a concatenation of superlatives and a string of astronomical words, what is it? The article "Rooms for Listening," which appears in the same issue, is interesting, instructive, easy to read and to understand. It illustrates the style which "The Layman's Science" would have one follow. What a contrast!

I quote from "On the Improvement of the Mind" by Isaac Watts, D.D., written about 1740: "Some persons have been led by education into a dark and unintelligible way of thinking and speaking; and this continues with them all their lives, and clouds and confounds their ideas: perhaps some of these may have been blessed with a great and comprehensive genius, with sublime natural parts, and a torrent of ideas flowing in upon them; yet for want of clearness in the manner of their conception and language, they sometimes drown their own subject of discourse, and overwhelm their argument in darkness and perplexity."

Although one of Watts's directions on "an instructive style" is that one "acquire a variety of words — a 'copia verborum,'" the above quotation suggests the possibility of a disease "maxima copia 'verborumitis.'" This last word is coined for good luck.

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MOTOR NECROLOGY

(*Continued from page 69*)

highway marking, better traffic regulation, elimination of grade crossings, use of clover-leaf intersections, stop signs, one-way streets, improved highway and car lighting, segregation of traffic, motor-vehicle inspection, compulsory insurance, educational programs, better automobiles, and so on without end. Although one shudders to think what the toll would have been without this work, one reluctantly turns to the conclusion that the answer to the problem does not lie in that direction. The evidence fairly screams that motor travel is continually pressing the bounds of its physical limitations and consistently, year after year, exceeding its human limitations. According to "Smash Hits of the Year," an entertaining little pamphlet broadcast by the Travelers Insurance Company, driver actions resulting in death in 1939 were classified as follows:

	Per cent of deaths
Exceeding speed limit	36.5
Reckless driving (within legal limit)	14.7
Drove off roadway	11.6
Passing on curve or hill	1.5
Cutting in	1.6
Passing standing street car	.2
	66.1
On wrong side of road	14.6
Did not have right of way	13.5
Passing on wrong side	1.0
Failed to signal and improper signaling	1.3
Car ran away — no driver	.2
Miscellaneous	3.3
	100.0

Speed was a factor in at least two-thirds of all deaths, and high velocity the cause of more than one-third.

A still further indication of the importance of speed is to be seen in the Travelers' analysis of the direction of travel of cars involved in fatal (*Continued on page 90*)

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MOTOR NECROLOGY

(*Continued from page 89*)

accidents. A large majority of such cars were not turning, backing, skidding, or standing still, but going straight ahead or slowing down (85.7 per cent of all deaths).

Within the total of motor necrology, changes are taking place, but they are mostly in the wrong direction. Victor W. Killick, chief of the bureau of statistics of the California Department of Motor Vehicles and a pioneer student of traffic problems, describes these trends by pointing out that the 60-70-80-miles-per-hour crashes are increasing in number; that the 100-miles-per-hour crash has arrived; and that within a short time we shall be hearing of the 120-miles-per-hour crash. The multi-death accident and the multicar accident, he concludes, are the latest aspects of the traffic problem.

On highways where there is a large, high-speed traffic flow, Killick observes, following cars may pile into a crash, compounding the accident; as many as fourteen cars have been involved in such a shambles. In former days, fatalities were chiefly of pedestrians. Literally, it was safer to ride than to walk; car collisions produced numerous injuries but few fatalities. Later, at higher speeds, a single death would occur and perhaps all passengers would be injured. In more recent high-speed crashes, however, impact forces are so terrific that a passenger has little chance to survive. "The multideath accident," Killick asserts, "is heavily responsible for the present skyrocketing of traffic fatality counts."

What can we do about it? We can of course continue to improve roads, cut down grades, reduce curves, increase visibility; we can continue to improve the mechanism of the automobile itself. But experience indicates that improvements of this sort are, after all, only palliatives. It seems to me, therefore, that we may find ourselves ultimately faced with the necessity of imposing some kind of universal restraint upon John Citizen when he gets behind the wheel of the family car for the Sunday afternoon spin. Two means of securing that restraint suggest themselves: the one mechanical; the other psychological, not to say spiritual.

The mechanical means is the automatic speed governor. The governor has fortunately been tried for some time, so that the results to be expected from universal adoption of it can be accurately forecast. A recent survey of opinion among 180 owners of motor fleets located in thirty-five states and operating some 50,000 vehicles found that no one who had voluntarily adopted the governors wanted to remove them. The device was declared to reduce accidents, according to 108 of the 180 owners; reductions in insurance costs up to 40 per cent were noted. Some of the installations appear to have been made primarily for economic advantages, but the effectiveness of the governor as a safety device in reducing accidents was almost universally acknowledged.

Rather interesting is the comment that the use of governors will have close consideration as a means of conserving rubber and oil consumption in time of war. Rubber offers one of the most difficult problems in the whole list of strategic materials, and its use is inseparably connected with automobiles and their speed of travel. The savings in human life and the economies in

operation, secondary considerations in war, would certainly be found worth keeping in the piping days of peace.

The spiritual, or psychological, means of enforcing universal restraint would ideally be to have John Citizen do his driving from the front bumper or the radiator cap of his car and thus to remove from him the seeming bulwark of overelongated hood and resonantly thrumming motor which now precede him in his mad dash down the highway. Several automobile manufacturers have experimented with rear-engined cars. One of the reasons they will not bring out such cars is the feeling of exposure to risk experienced by the driver when nothing is between him and what he might hit, in contrast to the sense of security he feels in the conventional car with the engine to take the brunt of the blow. These impressions are wholly illusory; the inertia of the occupant's body is the physical source of the human damage, and the inertia is the same in either case. From a safety standpoint, important advantages might be gained from putting the driver up front: He would be closer to the scene of a possible accident and in better time to avoid it; hundredths of a second are not to be despised. He would also, for his very fear — and fear is the emotional ingredient of caution — be in better emotional balance. The forward position would act in some degree as an automatic speed governor, through psychological channels.

THE INSTITUTE GAZETTE

(*Concluded from page 78*)

and Herbert B. King, '40, who made the project the subject of his thesis. The formula was established after a study of the various nutritive elements missing from the diet of the low-income group of the country's population. The food is composed of cereals, including wheat, corn, oats, and soya-bean meal, to which are added the required amounts of various minerals and concentrates. Energy and water requirements are supplied generally by even the poorest American diets. The new food cares for nutritional needs which often are not met by the average unbalanced menu. Vitamin C, which is not included in the formula, could be supplied by a daily ration of four ounces of tomato juice. The estimate that this food could be prepared at a cost per person of $1.80 a year aroused wide interest. Even the cartoonists found the subject appropriate.

THE TREND OF AFFAIRS

(*Concluded from page 60*)

L. Guzewicz, '32; Robert Ebenbach, '34; Rupen Eksergian, '14; Malcolm S. Hird, '26; and James M. Austin, Margaret Whitcomb, '39, and Delbar P. Keily, '34, of the Department of Meteorology. Various special problems were considered by Professors Charles W. MacGregor and Earle Buckingham, both of M.I.T.

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